

TAXONOMY AND DISTRIBUTION OF THE
FRESH-WATER SPONGES (SPONGILLIDAE)
OF MICHIGAN

Papers Mich. Acad. Sci., Arts and Letters, 15:439-477.
12 fig. 5 maps. 1931.

ENVIRONMENTAL SELECTION OF THE
FRESH-WATER SPONGES (SPONGILLIDAE)
OF MICHIGAN

Trans. Am. Microsc. Soc., 51:129-136. 1932.

CONTRIBUTION TO THE BIOLOGY OF
FRESH-WATER SPONGES (SPONGILLIDAE)

Papers Mich. Acad. Sci., Arts and Letters, 17:663-679.
1 fig. 1932.

OBSERVATIONS ON THE SISYRIDAE
(NEUROPTERA)

Papers Mich. Acad. Sci., Arts and Letters, 17:681-684.
1 fig. 1932.

MARCUS C. OLD

1933

TAXONOMY AND DISTRIBUTION OF THE
FRESH-WATER SPONGES (SPONGILLIDAE)
OF MICHIGAN

Papers Mich. Acad. Sci., Arts and Letters, 15:439-477.
12 fig. 5 maps. 1931.

ENVIRONMENTAL SELECTION OF THE
FRESH-WATER SPONGES (SPONGILLIDAE)
OF MICHIGAN

Trans. Am. Microsc. Soc., 51:129-136. 1932.

CONTRIBUTION TO THE BIOLOGY OF
FRESH-WATER SPONGES (SPONGILLIDAE)

Papers Mich. Acad. Sci., Arts and Letters, 17:663-679.
1 fig. 1932.

OBSERVATIONS ON THE SISYRIDAE
(NEUROPTERA)

Papers Mich. Acad. Sci., Arts and Letters, 17:681-684.
1 fig. 1932.

MARCUS C. OLD

A dissertation submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy
in the University of Michigan.

*20513



TAXONOMY AND DISTRIBUTION OF THE FRESH-WATER SPONGES (SPONGIL- LIDAE) OF MICHIGAN *

MARCUS C. OLD

SPONGILLIDAE are widespread over the earth, yet the literature dealing with them contains little more than fragmentary data, some of which are completely in error. Such errors, which have been copied over and over again, are greatly in need of correction. This paper is an attempt to add to the meager knowledge of the taxonomy and distribution of *Spongillidae* in the United States. It is anticipated that similar work will be done for other states in the near future. During the summer of 1929 the writer made a rather thorough ecological survey of sponge habitats that are scattered throughout the state of Michigan, and collections were made from eighty-four streams, forty-two lakes and nineteen ponds. These collections, together with earlier ones, comprise the basis of this report.

MATERIALS AND METHODS

A collapsible pneumatic rubber boat was used throughout the season to facilitate examination of parts of water units otherwise inaccessible. After collection and description, sponges were placed in low card boxes with absorbent paper bottoms and were exposed to the sun and air at every opportunity. Most specimens could be dried quite thoroughly in this fashion in from six to eight hours, but occasionally, if there was wet weather, or if the sponge was quite large, artificial heat had to be applied. After becoming quite dry, each specimen, together with its number and record

* Contribution from the Biological Station and the Zoölogical Laboratory of the University of Michigan.

was wrapped in two sheets of paper napkin and stored in small wooden boxes.

Upon the writer's return to the University in October, 1929, these sponges were filed in covered cylindrical cartons, which were marked on the outside in ink, to correspond with the number of the sponge on the inside, and arranged in series on shelves which afforded easy access for later examination. The condition of each sponge after shipment to the laboratory was excellent, differing from its original condition only in that it was drier, more fragile and paler.

Dried specimens of fresh-water sponges are more favorable for taxonomic purposes than specimens preserved in fluid. Fragments of dried sponge can be boiled easily and quickly in concentrated HNO_3 , without any accompanying formation of foam and explosions, such as result when the material has been soaked with formaldehyde or alcohol.

The methods of Annandale (1911), Arndt (1928a), Crawshaw (1915), Lendenfeld (1904), Potts (1887), Weltner (1909) and others have been tried, but a modified technic, as given below, has facilitated the work on which this paper is based.

SLIDE PREPARATIONS OF SPICULES

Representative portions of the sponge and its gemmules were placed in a test tube, 50×10 mm., containing about 0.25 c.c. of concentrated HNO_3 , and boiled over a low flame until the sponge mass had completely disintegrated. After cooling, the tube was filled with clean water, shaken thoroughly, and set aside to allow the spicules to settle. The fluid was then siphoned off with a suction pump, after which the tube was refilled with clean water and again shaken thoroughly. In this manner the spicules were washed a second time. After the fluid was withdrawn for the third time, it was replaced with 96 per cent alcohol — the amount needed depending on the quantity of spicule deposition in the tube — and shaken thoroughly. A portion of this alcoholic, temporary suspension of spicules was then immediately poured on a cover-slip, 7/8-inch circle No. 2, and ignited. Burning

the alcohol assured a quick and neat preparation, leaving the spicules clean and well distributed over the slip. A drop or two of the Damar mounting medium was then added and the slip inverted on a glass slide.

SLIDE PREPARATIONS OF GEMMULES

Gemmules of a selected specimen were placed in a test tube, 50 × 10 mm., containing 0.25 c.c. of cold concentrated HNO₃, and allowed to stand until the gemmules lost their opaqueness and became more or less cleared. Workers heretofore have always used hot HNO₃, but in the author's opinion cold HNO₃ is just as satisfactory and is less annoying. The gemmules were then washed several times in clean water and dehydrated by additions of 35, 50, 70, 82, and finally 96 per cent alcohol at about 15-to-30-minute intervals, and then cleared in carbol-xylol. The gemmules were removed with a camel's-hair brush and placed on a glass slide, to which the Damar mounting medium and a cover-slip were then added.

IDENTIFICATION OF SPECIES

Key to the fresh-water sponges of Michigan

In the construction of this key only the most essential systematic characters are used. Other distinguishing characters can be discovered by consulting the technical descriptions of the various species.

- | | | |
|----|--|--------------------------------|
| 1 | (8) Gemmule spicules either acerose or subcylindrical | 2 |
| 2 | (7) Skeleton spicules smooth amphioxi | 3 |
| 3 | (6) Flesh spicules present; amphioxous | 4 |
| 4 | (5) Flesh spicules spined | <i>Spongilla lacustris</i> |
| 5 | (4) Flesh spicules smooth | <i>Spongilla aspinosa</i> |
| 6 | (3) Flesh spicules absent | <i>Spongilla fragilis</i> |
| 7 | (2) Skeleton spicules spined | <i>Spongilla igloviformis</i> |
| 8 | (1) Gemmule spicules birotulate; more or less modified | 9 |
| 9 | (16) Birotulates of one class | 10 |
| 10 | (15) Rotules equal | 11 |
| 11 | (14) Shaft of birotulates longer than rotule diameter | 12 |
| 12 | (13) Rotules with 3-6 short recurved rays; shaft very much longer than rotule diameter | <i>Ephydatia crateriformis</i> |
| 13 | (12) Rotule discs not deeply serrate; shaft little longer than rotule diameter | <i>Ephydatia fluviatilis</i> |

- 14 (11) Shaft of birotulates of same length or shorter than rotule diameter; discs deeply serrate *Ephydatia mülleri*
 15 (10) Rotules unequal *Trochospongilla pennsylvanica*
 16 (9) Birotulates of two classes 17
 17 (22) Tubular foramen of gemmule, if present, not possessing filamentous appendages 18
 18 (19) Flesh spicules present; spined amphioxi *Heteromeyenia repens*
 19 (18) Flesh spicules absent 20
 20 (21) Rotules of smaller class finely serrate *Heteromeyenia ryderi*
 21 (20) Rotules of smaller class coarsely serrate *Heteromeyenia argyrosperma*
 22 (17) Tubular foramen of gemmule possessing filamentous appendages *Carterius tubisperma*

TAXONOMIC REVISIONS

Tubella pennsylvanica Potts is here designated *Trochospongilla pennsylvanica* (Potts), after the suggestion of Annandale (1911). The genus *Trochospongilla* is characterized by its smooth-margined birotulates. The smooth discs of the birotulates are not always of the same size; some birotulates show distinct differences in size. "Tubella" is reserved by Annandale to designate the forms in which the unequal birotulate discs differ not only in size but also in form. The small disc is a rounded knob; the larger is serrated and flat.

Annandale (1908) also suggested placing *Carterius tubisperma* Mills in the genus *Heteromeyenia*. Schröder (1927a), revising the genera *Carterius*, *Astromeyenia* and *Heteromeyenia*, classifies *Carterius tubisperma* Mills as *Heteromeyenia tubisperma* (Mills), and *Heteromeyenia repens* Potts as *Heteromeyenia baileyi* (Bwk.) var. *repens* (Potts). The author, however, is of the opinion that the remarkable appendaged tubular foramen is sufficiently distinctive to warrant the retention of the original genus created by Mills. Likewise, *H. repens* Potts appears sufficiently distinctive from *H. baileyi* (Bwk.) to stand alone.

EXTERNAL FEATURES

Fresh-water sponges cannot be identified positively by external features alone, since variations and similarities of appearance and surface morphology are too common. Frequently, a sponge may be recognized in the field by an examination of its

gemmules, as is the case with *S. fragilis*, *S. igloviformis* and *C. tubisperma*. Branched colonies are not always *S. lacustris*, and colonies of *S. lacustris* are not always branched. One is apt to conclude from the literature available that only *S. lacustris* may be a branched colony and that unbranched colonies of this species are abnormal. Branched colonies are also found in *S. aspinosa* and *H. repens*. Short, blunt, finger-like projections are found in *E. mülleri*, *H. ryderi*, *H. argyrosperma* and *C. tubisperma*.

The writer found unbranched and branched colonies of *S. lacustris* side by side in lakes and streams. The reason for this is not known. According to Carpenter (1928), the branched form occurs in lakes and the flat type in streams; the flat type is a response to an adverse condition caused by the rapidly flowing water. Her example is designated as "*Spongilla (Ephydatia) fluviatilis*," with illustrations of a lake form corresponding to *S. lacustris* and a running-water form corresponding to *E. fluviatilis*. Carpenter, apparently, confused two different species. Unbranched colonies were held by Annandale (1911) to be the result of unfavorable conditions. This can hardly be true when both forms are found side by side in the same water on similar supports.

ODOR

Van Trigt (1919) claimed the ability to distinguish *S. lacustris* from *E. fluviatilis* by its pungent smell, i.e. "pungent for instance as formol." This method, however, must remain a doubtful one. Fresh-water sponges have a peculiar characteristic odor, variously described as bad or similar to that of garlic. The latter description appears the better one to the writer; it served as a good field test for some of the fleshy sponges which otherwise have little resemblance to sponges, so far as a porous nature is concerned. Although the author has made use of this test in field recognition of sponges, he has not found it possible to distinguish by odor different genera or species of sponges. It is doubtful whether this characteristic odor of fresh-water sponges can be satisfactorily described on paper, for, apparently, recognition of it can come only through personal experience with the material.

GEMMULE PRODUCTION

According to Potts (1918), gemmules may be found on the rarer, filmy sponges as early as August, though on the more lusty, massive forms the gemmules may still be lacking late in November. Annandale (1911) states that in Europe, North America and Japan gemmules are produced at the approach of winter. The experience of the writer during the season of 1929 shows, however, that one may expect to find sponges with gemmules early in any favorable season. In fact, *S. fragilis* and *E. mülleri*, in a pond, were both found with new gemmules on June 27. By July 8, additional specimens bearing new gemmules included *S. fragilis*, *E. mülleri*, *E. fluvialis*, *T. pennsylvanica*, *H. repens*, *H. ryderi* and *C. tubisperma*. The only species which appeared to delay gemmule formation until late in the season (September or October) was *S. lacustris*, which was repeatedly taken in streams and lakes, but only occasionally bore gemmules in early summer. Of the total number of sponges collected (539), only 82 (15 per cent) could not be identified through lack of gemmules. Thus it is seen that sponges do not necessarily wait for the approach of winter to produce gemmules, although it should be stated that the probability of finding gemmules in large quantities is greater then than at the start of the favorable season. The production of gemmules at various times during the summer has been repeatedly observed in other years by the writer and his associates.

DESCRIPTIONS OF SPECIES

The general part of the descriptions, unless otherwise noted, consists of summaries of data accumulated by the author from *living* material. At the time of collection, data on the following characteristics were made for each sponge: habitat, shape and dimensions, surface, color, pores, texture, external membrane, basal membrane, and location, color and abundance of gemmules.

The part dealing with the spicules and foramen of gemmules is a composite description built from all the slide material for the species.

The descriptions are unique in that they represent a summary of many individual descriptions made from sponges scattered over the state of Michigan. The descriptions are, therefore, comprehensive instead of narrow in their application.

Spongilla aspinosa Potts

Jewell and Brown (1929) found this sponge growing abundantly in an acid lake (Malony Lake, Cheboygan Co., Michigan; pH 5.0), attached to fragments of wood and the soft false bottom, but give no technical description of it. The following characters are taken from Potts (1887):

Skeleton spicules smooth amphioxi; straight or slightly curved; rather abruptly pointed.

Flesh spicules minute amphioxi; straight or curved; smooth; slender.

Gemmule spicules resemble the skeleton spicules.

This species did not occur in any of the writer's collections. Apparently, it is rare in Michigan.

Annandale (1916) reports a specimen from Lake Biwa, Japan, under the name *S. aspinosa*, which differs from the type in that it possesses spined flesh spicules. The gemmules are surrounded by an irregular but dense network or cage of skeleton spicules.

Spongilla lacustris Auctorum

Sponge found in quiet or rapidly flowing water, attached usually to upper side of stones, timber and vegetation. Body usually soft and loose with a well-marked external membrane; colonies of two types, branched and unbranched. Color green in sunlight; a gray, yellow or orange in constant shade. Filaments of branching type sometimes attaining length of 10-11 inches, and a width of 1/4-5/16 inch; flat spreading type sometimes 9 × 4 inches or more; spindle-shaped colonies attaining a length of 8 inches and thickness at middle about 3/4-1 inch. Gemmules yellow or orange; distributed all through sponge body; foraminal aperture infundibular.

Skeleton spicules smooth amphioxi; straight or slightly curved;

variable in length and breadth in same specimens and to greater extent in different specimens.

Flesh spicules finely spined, slender amphioxi; straight or slightly curved.

Gemmule spicules subcylindrical; ends pointed or rounded; variably curved or straight; spined.

Spongilla fragilis Leidy

(Pl. XXXV, Figs. 1-4)

Sponge found in both quiet and running water on upper or lower side of submerged stones and wood as flat spreading colonies, as large as 12×15 inches; or on twigs, branches and similar objects, usually forming spindle-shaped colonies as much as 16 inches long and $1\frac{1}{2}$ inches thick at middle; or on muddy, sandy or gravel bottoms as globular colonies. Body rather firm; surface rugged, occasionally quite smooth; oscula in well-developed specimens large and conspicuous, often somewhat raised; external membrane usually noticeable. Thickness of sponge frequently $\frac{1}{8}$ - $\frac{1}{4}$ inch; in largest specimens $1\frac{1}{2}$ -2 inches. Color usually green, but when growing in constant shade, gray, yellow, brown or pink; muddy or stained waters, or supporting materials may impart unusual shade of brown, lavender or chocolate color. Gemmules bound together in free groups of varying numbers or in pavement layer on support; color, depending on age, varying from whitish through yellow, orange and dark brown; foraminal aperture prolonged into tubes on outside, frequently curved.

Skeleton spicules smooth amphioxi; straight or nearly so; varying in length, breadth and degree of sharpness in same specimen, but to greater extent in different specimens (Figs. 1-4 A). Spicules occasionally with globular swellings at middle, or series of globular swellings along axis. Abnormal skeleton spicules (Schulze, 1923) rarely present (Fig. 4 C); also spicules with distinct axial canals.

Flesh spicules wanting.

Gemmule spicules spined amphioxi or amphistrongyli; straight or slightly curved; length, breadth, termination and quality of

spination may vary in same specimen. Certain specimens with spined subcylindrical spicules (Fig. 1 B); others with spined acerates (Fig. 2 B); still others with mixture (Figs. 3-4 B). Abnormal gemmule spicules (Schulze, 1923) with distinct axial canals and subcanals extending into spines also present (Fig. 1 C). Abnormal spicules in form of pynasters or sphaerasters (Fig. 3 C) present in some specimens.

Spongilla igloviformis Potts

Sponge abundant in sheltered cove of lake on the bottoms and sides of submerged 10-12-inch logs. Body thin, incrusting, fleshy; surface smooth, except projecting points of skeleton spicules. Average size 7×3 inches. Color variable: light grayish, light brown, dark brown or green. Gemmules yellow to orange, in scattered hemispherical groups upon substratum. Cellular parenchyma surrounding gemmule groups; tubules turned inward.

Skeleton spicules slender spined amphioxi; not abundant; spines coarse, scattered.

Flesh spicules wanting.

Gemmule spicules like skeleton spicules, but generally shorter and more numerous.

Trochospongilla pennsylvanica (Potts)

(Pl. XXXVI, Figs. 6-7)

Sponge found in relatively quiet water usually beneath stones, timber, twigs, and the like, rarely on upper side of objects. Body thin, fragile; surface even, smooth; external membrane usually noticeable. Colonies mostly small, none exceeding $4 \times 1 \frac{1}{2}$ inches. Prevailing color gray, occasionally green or light yellow. Yellow gemmules scarce, occurring free in sponge body; foramen infundibular.

Skeleton spicules abundantly spined; ends rounded or pointed; length and breadth (Figs. 6-7 A) varying in different specimens.

Flesh spicules wanting.

Gemmule spicules unequal birotulates. Shaft smooth; with smooth-margined disc at one end and minute disclike structure

at other end. Some specimens exhibit an additional kind of unequal birotulate possessing a large disc with six or more distinct rays leading from shaft almost to margin of disc (Figs. 6-7 C).

Ephydatia crateriformis (Potts)

One specimen found incrusting lower side of plank in sluggish stream; body very thin, flat and spreading; size, 7×5 inches. Color white, owing to abundance of white gemmules lying against substratum.

Skeleton spicules slender amphioxi; sparsely macrospined.

Flesh spicules wanting.

Gemmule spicules of birotulate type; shafts cylindrical, long, and macrospined mostly toward ends; rotules with 3-6 short, recurved rays.

Ephydatia fluviatilis (Auctorum)

Sponge found on upper and lower sides of timber, stones, branches, roots and the like, in quiet or rapidly flowing water partially shaded. Body quite hard, firm; surface usually irregular with blunt lobular projections, or very even; oscula prominent, circular; forms subcircular spreading patches varying from those one-half inch in diameter to areas of about 400 square feet, continuously distributed over bed of stones and gravel. Color dark yellow, or cream, light or dark yellow, brown and green. Gemmules abundant and free throughout body of sponge, or in basal region; foramen infundibular, inconspicuous.

Skeleton spicules smooth amphioxi; occasionally with few microspines.

Flesh spicules wanting.

Gemmule spicules birotulates; shafts longer than diameter of rotule; rotule moderately serrate. Shafts usually smooth; sometimes spined to lesser or greater degree.

Ephydatia mülleri (Lieberkühn)

(Pl. XXXVI, Fig. 5)

Sponge found attached to stones, timber, vegetation, and similar objects, in quiet as well as rapidly running water; body

fragile; surface rarely even, usually rugose, or with close stout finger-like projections attaining length of 1 1/4 inches; color green, yellow, brown, or gray. Gemmules of various shades of yellow and orange; scattered throughout sponge.

On timbers or on cement abutments of bridges sponge may develop to a length of 40 inches and a width of 20 inches, with a depth of 4 inches at middle; spindle-shaped colonies coating slender branches may become 16 inches long and 5 inches wide.

Skeleton spicules smooth to abundantly spined amphioxi; straight or slightly curved; all kinds occasionally in same specimen.

Flesh spicules wanting.

Gemmule spicules birotulates; shaft of same length or shorter (usually) than diameter of rotule; rotules flat; irregularly and deeply serrate, depth of serration almost to hub of rotule. Occasionally many malformations (Fig. 5 B) (Wierzejski, 1912). Gemmule spicules in more than one layer in some specimens.

Heteromeyenia repens Potts

(Pl. XXXVII, Figs. 11-12)

Sponge found in quiet and slowly running water, coating twigs, roots, leaves, wood and vegetation. Body rather loose; surface quite smooth, rugose or elevated into short narrow projections, often subbranched on submerged finely divided vegetation; external membrane usually wanting. Most frequent on upper side of objects, growing to length of 8 inches and thickness of about 1/8 inch. Color green or whitish. Yellow gemmules free in body of sponge at or near base.

Skeleton spicules amphioxi; sparsely spined or smooth (Figs. 11-12 A); straight or slightly curved; length and breadth of spicules vary to great extent in different specimens.

Flesh spicules heavily spined amphioxi; straight or curved; spines (Figs. 11-12 D) perpendicular and longest at middle.

Gemmule spicules of two classes; small birotulates with moderately serrated rotules and smooth shafts (Figs. 11-12 B), or at most possessing few spines; larger birotulates with rotules of

many distinct, recurved spines; shafts (Figs. 11-12 C) usually with one or more macrospines near middle.

Heteromeyenia ryderi Potts

(Pl. XXXVII, Figs. 9-10)

Sponge found in quiet or slowly running water, usually incrusting bottoms of stones, timber or vegetation. Body rather loose and watery, not attaining great size; surface in larger specimens interrupted by thin, very short projections; smaller specimens smooth; external membrane present or wanting; forming irregular low masses, 1/4-3 inches in greatest diameter. Color gray, yellow or green. Gemmules free in tissues of sponge at or near base; recognizable as minute white or yellow grains.

Skeleton spicules spined amphioxi; straight or slightly curved; length and amount of spination variable in different specimens (Figs. 9-10 A), depending probably on maturity of sponge.

Flesh spicules wanting.

Gemmule spicules birotulates of two classes; smaller class with well-developed rotules finely serrated and usually with smooth shaft; larger class with rotules of heavy recurved spines and shaft usually possessing one or more spines and swelling at middle (Fig. 10 C); one immature specimen exhibited gemmule spicules (Fig. 9 B-C), although no gemmules could be isolated.

Heteromeyenia argyrosperma Potts

Sponge incrusting upper and lower sides of stones, timber and vegetation in quiet or rapidly running water. Body quite loose, thin; surface often more or less even; on finely divided vegetation, short narrow filaments as much as 1 inch long and 1/8 inch wide usually present; external membrane sometimes with a slime. Maximum size, 6 × 3 inches; flat, spreading. Gemmules yellow, free in body of sponge near basal region.

Skeleton spicules amphioxi; sparsely spined; spines projecting toward extremities of spicule.

Flesh spicules wanting.

Gemmule spicules birotulates of two classes; larger class robust

with long shafts, usually with long recurved spines; rays of rotules clawlike. Shorter class abundantly spined; rotules flatter with rays irregularly hooked.

Carterius tubisperma Mills

Sponge attached to submerged stones, wood, vegetation, usually, on upper side, in quiet or rapidly flowing water. Body soft and cushion-like; external membrane usually present; surface rarely even, mostly rugose or with many close-set short projections, $1\frac{1}{8}$ – $1\frac{1}{4}$ inch long. Largest specimen collected by writer, attached to gravel and overspreading it on creek bed, 20 inches long, 8 inches wide, 4 inches thick. Color usually green, occasionally brown or yellow. Gemmules yellow; free in basal portion of sponge.

Skeleton spicules sparsely microspined amphioxi; occasionally smooth; length and breadth mostly uniform in same specimen, but varying in different specimens.

Flesh spicules long slender amphioxi; straight or slightly curved; entirely spined; spines at middle longest.

Gemmule spicules birotulates; irregular in length, suggesting two classes; larger birotulates with rotules of distinct recurved rays; smaller ones usually with flat rotules showing distinct rays; shafts of both kinds occasionally smooth, usually more or less macrospined.

This sponge can be recognized in the field with a common hand lens. An examination of the gemmules will reveal a tubular foramen ending in 4–6 long slender tendrils.

DISCUSSION

Variation in spicules. — Sponges have been commonly described from single or few specimens from the same or different localities, with the result that consequent narrow descriptions have encouraged further designations of varieties and subspecies. The writer has purposely avoided varieties and subspecies because he believes the taxonomy of fresh-water sponges is better served without them until more data will have been accumulated.

The literature contains numerous examples of variation among sponges which have been incorporated into varieties or subspecies, and which later have been revised as "simply a very common variant form of a highly variable species" (Smith, 1921a).

S. fragilis, of which one hundred and sixty-eight specimens were collected, shows four variations in form and kind of spicules, not one of which is sufficiently distinctive to justify designation as a variety.

Some of the material included under *Trochospongilla pennsylvanica* in this paper may possibly belong to a new species of that genus. Thus far descriptions have contained no mention of gemmule spicules in which some smooth-margined discs are rayed (Pl. XXXVI, Figs. 6-7 C), but they are otherwise similar to those of the type specimen. This could probably be designated a variety or subspecies. The author prefers, at present, to list this form as *T. pennsylvanica*.

E. mülleri, as has been noted by others, is also a highly variable species in Michigan. This is evident not only in the quality of spination of the skeleton spicules, but also in the extreme types of gemmule amphidiscs. Rotules may be entirely missing and may possess only a few rays irregularly placed; or the rays of the rotules may present various conditions of spination. Ordinary amphidiscs and these extreme forms usually occur together.

One specimen of *H. repens* shows smooth instead of sparsely spined skeleton spicules. In this respect it agrees with *Heteromeyenia insignis* Weltner (1895). *H. insignis* is further described with numerous spines on all birotulates and with long spines of the flesh spicules terminating in a knob. Since the Michigan specimen represents but one collection and differs in some minor characters, one hesitates to designate it *H. insignis*, a species which is recorded only from Brazil. Specimens occur in which the spinose character is weak, and it is conceivable that a condition might arise in which the skeleton spicules are aspinose.

Globular swellings at the middle of spicules, or a series of globular swellings, are found in some preparations. Such swellings have been recorded by Arndt (1926), Müller (1911), Wierzejski (1912) and others for practically all the common species, in both

immature and adult specimens. In the writer's collection it has been noted that such swellings occur mostly on slender skeleton spicules from small specimens growing on decaying leaves and soft stems or on rotting timber. This fact has not been mentioned by previous workers, who are unable to account for the swellings. Circumstantial evidence suggests that possibly these swellings result from pathological conditions arising from the decay of the supporting substance. Nothing definite, however, can be stated at this time.

Unusual skeleton spicules. — In the fall of 1927 the writer found peculiar modifications in skeleton spicules in two sponges from the Grand River, near Lansing, Michigan. One colony, a rock-incrusting form of *E. fluviatilis*, with an abundant growth of filamentous algae mixed in it, contained many skeleton spicules with wide axial canals, open at both ends, which occupied more than one half of the breadth of the spicule. Slides prepared by boiling spicules in both HNO_3 and KOH showed it. Similar skeleton spicules have been noted by Potts (1884) from specimens of *Trochospongilla leidyi* discolored by rust from pipes of water-works. Potts believed the modification to be due to a chemical condition in the environment.

The other colony, growing about a mass of filamentous algae, unfortunately was very small and flimsy; it contained no gemmules and therefore its identity is unknown. Collections were repeatedly made later, but no other specimens exhibiting these peculiarities could be found. Figures 8 A–F, Plate XXXVI, represent the various conditions among the skeleton spicules. Normal amphioxi with only a bare hint of an axial thread are present but scarce; others may show a wide canal at one end only (A, C); others at both ends (B); in still others — and these are by far the most numerous — it seems that the ends of the spicules are curled back, crispate (D–F). These conditions appear to be the result of an internal decay that reduces the spicule at the ends to a mere shell, which subsequently curls back on itself.

Many of the amphioxi (A–B) show what seems to be a peculiar cap enveloping the extremity. This sheathlike structure surrounding one or both ends is a thick-walled empty cap, over-

lapping the outer end of the spicule for a short distance, and occasionally the cavity of this structure may be seen extending into the lumen of the spicule. Later, this structure probably splits and breaks (C-D), producing the curled ends (E-F). It is possible that the splitting and curling may have been due to contact with hot HNO_3 in making the spicule slide preparation.

Duncan (1881) has noticed some enlargements of the axial canals in marine sponges and concludes that they are caused by an organism that penetrates and erodes the silica. Both specimens under consideration were infected with filamentous algae, a fact which may be worthy of notice. The waters in which they were found are polluted with industrial wastes. It is probably an environment with a peculiar chemical nature, yet the stream at this point is luxuriant in sponges which seldom show any malformations. Owing to lack of material, further search concerning the probable cause is impossible, and the peculiarity of the spicules is mentioned now only to point out a condition hitherto undescribed.

DISTRIBUTION IN MICHIGAN

(Map 4)

Below are given the locality records for each species found in Michigan till the date of writing this report (February, 1930). Records other than those of the author are shown in parenthesis.

Spongilla aspinosa Potts

(Map 5)

CHEBOYGAN COUNTY: Malony Lake (Jewell, 1929).

Spongilla lacustris Auctorum

(Map 5)

ALPENA COUNTY: Devil River; BARAGA COUNTY: Ruth Lake; BRANCH COUNTY: Swan Creek; CHARLEVOIX COUNTY: Susan Creek; CHEBOYGAN COUNTY: Bessey Creek, Blanchard Lake, Brown Lake (Jewell, 1929), Maple Bay of Burt Lake, Maple River (Smith, 1915), Mud Lake (Jewell, 1929), Nigger Creek;



MAP 4. Distribution of new and old locality records

CHIPPEWA COUNTY: Whitefish Point (Hankinson, 1916a); CLINTON COUNTY: Lookingglass River; DELTA COUNTY: Days River; EATON COUNTY: Pine Lake; EMMET COUNTY: Crooked River; HOUGHTON COUNTY: South Twin Lake and Stonington Lake (Hankinson, 1916), Beaver Dam Lake; KALKASKA COUNTY: small lake near Kettle Lake; KEWEENAW COUNTY: Lake Fanny Hooe and inlet, lake on Isle Royal (Adams, 1908); LUCE COUNTY: Twin Lakes; MACKINAC COUNTY: lake near Garnet; MACOMB COUNTY: lake near Romeo; MARQUETTE COUNTY: Horseshoe Lake; MENOMINEE COUNTY: lake near Hermansville, Wilson Creek; NEWAYGO COUNTY: Blanch Lake, Brooks Creek; OAKLAND COUNTY: lake near Walled Lake, Clinton River; ONTONAGON COUNTY: Ontonagon River, Merriweather Creek, Carp Creek (Adams, 1908); OSCODA COUNTY: North Helmar Lake; OTSEGO COUNTY: Lake near Gaylord; OTTAWA COUNTY: Grand River (Smith, 1921); PRESQUE ISLE COUNTY: Ocqueoc Creek, Swan River, Twin Lakes; SCHOOLCRAFT COUNTY: Indian River; ST. CLARE COUNTY: Pine River; WASHTENAW COUNTY: Third Sister Lake, Whitmore Lake.

Spongilla fragilis Leidy

(Map 5)

ALPENA COUNTY: Thunder Bay River, Devil River; BARRY COUNTY: Mud Lake; BAY COUNTY: drainage stream; BRANCH COUNTY: stream near Quincy; CALHOUN COUNTY: Garfields Lake; CASS COUNTY: stream in Marcellus Township; CHEBOYGAN COUNTY: Bessey Creek (Smith, 1915), Blanchard Lake, Indian River (Smith, 1915), Maple Bay of Burt Lake (Smith, 1915), Nigger Creek, Sedge Pool (Smith, 1915), Smith's Bog (Smith, 1915, and Jewell, 1929); CHIPPEWA COUNTY: Carp Lake, Whitefish Point (Hankinson, 1916a); CLINTON COUNTY: Lookingglass River; EATON COUNTY: Pine Lake, Grand River; EMMET COUNTY: Crooked River; GENESEE COUNTY: Goudy Lake; GLADWIN COUNTY: dry pond, south side of Indian Lake; GOGEBIC COUNTY: Sunday Lake, Tenderfoot River; GRAND TRAVERSE COUNTY: pond near Kingsley;



MAP 5. Distribution of records of *Spongilla aspinosa*, *S. lacustris*, *S. fragilis* and *S. igloviformis*

GRATIOT COUNTY: Pine River, pond near Perrinton; HILLSDALE COUNTY: stream in Scipio Township, stream in Hillsdale Township; HOUGHTON COUNTY: Snake River, South Twin Lake (Hankinson, 1916); INGHAM COUNTY: Cedar River, drainage stream from Huntoon Lake; IOSCO COUNTY: Hale Creek; IRON COUNTY: Tamarack River, Iron River, Fortune Lakes; JACKSON COUNTY: stream near Jackson; KALKASKA COUNTY: Black River; KENT COUNTY: Little Egypt Creek; KEWEENAW COUNTY: Fanny Hooe Creek, Lake Fanny Hooe, Chickenbone Lake on Isle Royal; LAPEER COUNTY: pond near North Branch, Flint River; LEELANAU COUNTY: Glen Lake; LENAWEЕ COUNTY: stream near Cambridge, Raisin River; MACKINAC COUNTY: lake near Garnet; MACOMB COUNTY: stream and lake near Romeo; MARQUETTE COUNTY: Horseshoe Lake, Morgan Creek, creek near Michigamme; MECOSTA COUNTY: Dead Stream; MENOMINEE COUNTY: lake near Hermansville; MISSAUKEE COUNTY: Clam River; OAKLAND COUNTY: Clinton River; OCEANA COUNTY: (Smith, 1921); ONTONAGON COUNTY: Merriweather Creek; OTESGO COUNTY: lake near Gaylord; OTTAWA COUNTY: Grand River (Smith, 1921); ROSCOMMON COUNTY: Au Sable River pond, stream between Higgins Lake and Marl Lake; SAGINAW COUNTY: Cass River; SCHOOLCRAFT COUNTY: Indian River; St. JOSEPH COUNTY: pond near Centreville, Prairie River; TUSCOLA COUNTY: drainage stream, Cass River; VAN BUREN COUNTY: lake in Almena Township; WASHTENAW COUNTY: four ponds in vicinity of Ann Arbor, pond near Frains Lake, Huron River, (Smith, 1921); WAYNE COUNTY: Huron River, Marsh Creek; WEXFORD COUNTY: pond in Boon Township.

Spongilla igloviformis Potts

(Map 5)

ALGER COUNTY: Ackerman Lake.



MAP 6. Distribution of records of *Ephydatia mülleri*, *E. fluviatilis* and *E. crateriformis*

Ephydatia crateriformis (Potts)

(Map 6)

CHEBOYGAN COUNTY: Smith's Bog (Jewell, 1929); SAGINAW COUNTY: Shiawassee River (Smith, 1921, 1921a); WAYNE COUNTY: Marsh Creek.

Ephydatia fluviatilis (Auctorum)

(Map 6)

BAY COUNTY: drainage stream; CHEBOYGAN COUNTY: Bessey Creek (Smith, 1915); EATON COUNTY: Grand River; GLADWIN COUNTY: dry pond near Indian Lake; JACKSON COUNTY: Kalamazoo River; TUSCOLA COUNTY: two separate drainage streams.

Ephydatia mülleri (Lieberkühn)

(Map 6)

ALPENA COUNTY: Thunder Bay River; BRANCH COUNTY: Swan Creek; CALHOUN COUNTY: Nottawaseppe River, Bedford Mill Pond; CHARLEVOIX COUNTY: Adams Creek; CHEBOYGAN COUNTY: Bessey Creek, Blanchard Lake, Burt Lake (Smith, 1915), Crooked River (Smith, 1915), Indian River (Smith, 1915), Maple River (Smith, 1915), Nigger Creek; CHIPPEWA COUNTY: (Hankinson, 1916a); CLARE COUNTY: pond near Harrison; CRAWFORD COUNTY: Au Sable River; DELTA COUNTY: Days River; GLADWIN COUNTY: stream near Gladwin, dry pond near Indian Lake; GOGEBIC COUNTY: Morrison Creek; HILLSDALE COUNTY: lake near Osseo; HURON COUNTY: Rock Falls Creek, Pigeon River; IRON COUNTY: Tamarack River, Iron River; KALAMAZOO COUNTY: Portage Creek, Mud Lake Creek; KALKASKA COUNTY: Black Creek; KEWEENAW COUNTY: Fanny Hooe Creek, Lake Fanny Hooe; LEELANAU COUNTY: Glen Lake, Crystal River; LENAWEE COUNTY: stream near Cambridge, Raisin River; LIVINGSTON COUNTY: Nichwaugh Lake; MACKINAC COUNTY: lake near Garnet; MARQUETTE COUNTY: Horseshoe Lake; MONTCALM COUNTY: two streams, one north of Sheridan, the



MAP 7. Distribution of records of *Heteromeyenia repens*, *H. ryderi* and *H. argyrosperma*

other northeast of Sheridan; MUSKEGON COUNTY: Crockery Creek; NEWAYGO COUNTY: Robinson Creek; OAKLAND COUNTY: creek near Wolverine Lake; OTTAWA COUNTY: Black Lake (Smith, 1915); OTSEGO COUNTY: pond on east side of Otsego Lake; PRESQUE ISLE COUNTY: pond (Smith, 1915); SCHOOLCRAFT COUNTY: Indian River; ST. CLARE COUNTY: Pine River; VAN BUREN COUNTY: Paw Paw River, Brandywine Creek; WASHTENAW COUNTY: pond near Ann Arbor, Huron River at Ann Arbor, Third Sister lake.

Heteromeyenina repens Potts

(Map 7)

ALCONA COUNTY: pond near Crooked Lake; CHEBOYGAN COUNTY: East Lake, beach pools (Smith, 1915), Burt Lake (Smith, 1915), Smith's Bog (Smith, 1915); LIVINGSTON COUNTY: stream near Brighton; OSCODA COUNTY: North Helmar Lake; OTTAWA COUNTY: Black Lake (Smith, 1915); OTSEGO COUNTY: pond on east side of Otsego Lake; ST. JOSEPH COUNTY: pond near Centreville; WASHTENAW COUNTY: Huron River (Smith, 1915).

Heteromeyenina ryderi Potts

(Map 7)

BARRY COUNTY: Mud Lake, Crooked Lake; CHEBOYGAN COUNTY: Bessey Creek and Smith's Bog (Smith, 1915); LENAWEE COUNTY: stream near Cambridge; MARQUETTE COUNTY: Horseshoe Lake; ONTONAGON COUNTY: Merriweather Creek; ROSCOMMON COUNTY: Au Sable River.

Heteromeyenina argyrosperma Potts

(Map 7)

CHEBOYGAN COUNTY: Smith's Bog (Smith, 1915); GOGEBIC COUNTY: Sunday Lake; HOUGHTON COUNTY: Beaver Dam Lake; MARQUETTE COUNTY: Horseshoe Lake; ONTONAGON COUNTY: Ontonagon River, Merriweather Creek; OTSEGO COUNTY: pond east of Otsego Lake.



MAP 8. Distribution of records of *Carterius tubisperma* and
Trochospongilla pennsylvanica

Trochospongilla pennsylvanica (Potts)

(Map 8)

BARAGA COUNTY: Ruth Lake; CHEBOYGAN COUNTY: Smith's Bog (Smith, 1915); GOGEBIC COUNTY: Sunday Lake; HOUGHTON COUNTY: Beaver Dam Lake; LEELANAU COUNTY: Glen Lake, Crystal River; ONTONAGON COUNTY: Merriweather Creek; SCHOOLCRAFT COUNTY: Indian River; VAN BUREN COUNTY: lake in Almena Township.

Carterius tubisperma Mills

(Map 8)

BARRY COUNTY: Crooked Lake; BAY COUNTY: drainage stream; CHEBOYGAN COUNTY: Maple Bay of Burt Lake, Bessey Creek and beach pools (Smith, 1915); CLINTON COUNTY: Looking-glass River; DELTA COUNTY: Days River; EATON COUNTY: Grand River; EMMET COUNTY: Crooked River, French Farm Creek; GOGEBIC COUNTY: Tenderfoot River; GRATIOT COUNTY: Pine River; HURON COUNTY: Pigeon River; INGHAM COUNTY: Cedar River; KALAMAZOO COUNTY: Portage Creek; LAPEER COUNTY: lake near North Branch; LIVINGSTON COUNTY: Nichwaugh Lake; MENOMINEE COUNTY: lake near Hermansville, Wilson Creek; MONTCALM COUNTY: stream northeast of Sheridan; NEWAYGO COUNTY: Robinson Creek; SAGINAW COUNTY: Cass River; SHIAWASSEE COUNTY: Shiawassee River; ST. JOSEPH COUNTY: Prairie River; TUSCOLA COUNTY: drainage stream; WASHTENAW COUNTY: Huron River.

DISCUSSION

Relative abundance of species

Michigan includes within her boundaries representatives of five of the seven genera of fresh-water sponges known for North America. *Spongilla aspinosa*, *S. lacustris*, *S. fragilis*, *S. igloiformis*, *Trochospongilla pennsylvanica*, *Ephydatia crateriformis*, *E. mülleri*, *E. fluviatilis*; *Heteromeyenia repens*, *H. ryderi*, *H. argyro-*

sperma and *Carterius tubisperma*, or a total of twelve species, are now known to occur in the state. Some are apparently rare; others are quite common. Table I gives a rough estimate of the comparative abundance of each species according to the number of collections made.

TABLE I

COMPARATIVE ABUNDANCE OF SPECIES OF SPONGILLIDAE IN MICHIGAN

Species	No. of collections	Percentage of total	Order of abundance
<i>S. aspinosa</i> . . . . .	...	....	..
<i>S. lacustris</i>	39	14.3	4
<i>S. fragilis</i>	77	28.2	1
<i>S. igloviformis</i>	1	0.4	9
<i>T. pennsylvanica</i>	9	3.3	6
<i>E. crateriformis</i>	1	0.4	9
<i>E. mülleri</i>	44	16.0	3
<i>E. fluviatilis</i>	7	2.7	8
<i>H. repens</i>	7	2.7	8
<i>H. ryderi</i>	8	2.9	7
<i>H. argyrosperma</i>	7	2.7	8
<i>C. tubisperma</i>	25	9.2	5
Immature forms	47	17.2	2
Total collections	272		

Collections were made from eighty-four streams, forty-two lakes and nineteen ponds. Though the author made every effort to avoid any conscious selection of habitats and examined all possible environments at every opportunity, still these data cannot be interpreted as a final index of the relative abundance of the different species, since it would undoubtedly vary with the kinds of waters examined.

S. lacustris, usually thought of as the most common fresh-water sponge, is outnumbered by *S. fragilis* and *E. mülleri*. *E. fluviatilis*, instead of having a wide distribution, is found to be limited to six counties of the eastern part of the Lower Peninsula. *S. igloviformis* is known only from Ackerman Lake, Alger County. *S. aspinosa* is recorded only from Malony Lake, Cheboygan County. *E. crateriformis* has been found in three widely separated

waters: Smith's Bog, Cheboygan County; Shiawassee River, Saginaw County; and Marsh Creek, Wayne County. *H. ryderi* occurs in the western part of the Upper Peninsula and in the northern and southern parts of the Lower Peninsula; *H. repens*, in the southern and northern parts of the Lower Peninsula only; *H. argyrosperma* is limited to the Upper Peninsula and the northern part of the Lower Peninsula. *T. pennsylvanica* appears in the Upper Peninsula, the northern part of the Lower Peninsula, and in the southwestern corner of the state. *C. tubisperma* is more widespread than expected, being missing only from the central part of the Lower Peninsula. *S. lacustris*, *S. fragilis* and *E. mülleri* are apparently the only species now spread over the entire state. Further collections will probably extend the range of at least some of the species mentioned above.

Best collecting grounds

The best collecting grounds for fresh-water sponges in Michigan appear to be in the Upper Peninsula. Not only is the percentage of waters containing sponges greater, but each water is apt to harbor from three to five different species. In most parts of the Lower Peninsula sponge habitats are relatively scarce as compared with the number of waters, and usually not more than two species are found together. Beautiful and luxuriant growths of sponges were found only in certain waters which were completely free from the influences of man. Especially is this true of Horseshoe Lake, between Negaunee and Marquette, in which all possible submerged objects were utilized as a base for at least five different species, which displayed varied and remarkable forms.

Stephens (1920) is of the opinion that sponges in Ireland grow in greatest luxuriance "in a stream or river which drains a lake, and at a point a greater or less distance below the lake." This is evident in Michigan, especially in Bessey Creek, which drains Lancaster Lake into Douglas Lake. Luxuriant growths, however, were also found in streams not draining lakes and in the smaller lakes themselves. The writer is of the opinion that there are too many exceptions to the rule to allow one to generalize con-

cerning the most favorable water. It has not been his experience to find the best specimens in the most rapid currents, notwithstanding the statement of Potts (1887) to the contrary.

Variety of habitats

Potts (1918) cautions sponge collectors not to "waste time in hunting along sluggish streams or in shallow muddy ponds." Morgan (1930) states that "Sponges can live only in clean water." On the other hand, the experience of the past few years convinces the writer that no waters should be overlooked. In fact, many sponges were found in such streams and ponds. Globular colonies, 1-1 1/2 inches in diameter, were occasionally found growing on the mud bottoms of ponds, as well as other forms on submerged wood, vegetation or dead leaves. Highly colored waters also contained many growths of sponges. Specimens of *S. fragilis*, *S. lacustris* and *E. mülleri* were found in abundance attached to copper-bearing rocks in the Keweenaw Peninsula. The color of many of these colonies was a sort of lavender. Hay (1903) discovered a quantity of *S. fragilis* in Echo River within Mammoth Cave, Kentucky.

Other sites which must not be overlooked in making extensive surveys are the dried bottoms of former bodies of water. Late in the summer during this survey the writer came across many dry ponds and streams, or a dry portion of a lake formerly inundated, which yielded numerous specimens. Wood and other solid supports were frequently found bearing abundant dry fragile specimens with many gemmules.

Basins or water courses which have been dry, but which may have accumulated water again even after a few years, must also not be overlooked. Many ponds dry up in the summer season, yet sponges appear again the following spring. According to Weltner (1893), gemmules of *S. lacustris* germinated after being collected from a pond that had been dry for three years; Zytkoff raised sponges from gemmules of *E. mülleri* that had been dry for two years; Carter had gemmules germinate after they had been dry from seven to eight years. Weltner tried to raise sponges from

gemmules of *T. vesparium* and *S. carteri* that had been dry twenty and thirty years, respectively, but did not succeed. At any rate, it appears that some gemmules may withstand several years' desiccation without injurious effect, and one may expect to find sponges on dry bottoms of former waters and also in bodies of water which have come into existence again after being dry for several years. In South America, on the banks of the Amazon, sponges have been found on the branches of bushes and trees which are submerged only during the rainy season.

Polluted waters

Until this date (1930) it has been supposed that sponges have been eliminated from contaminated waters, although the two following records from the literature hint at a different conclusion. Potts (1887) found sponges occasionally in water "unfit for domestic uses," and Annandale (1911) reports that in India sponges apparently prefer waters unfit for domestic purposes, i.e. polluted by human agencies, and some species are known to occur only in such water. In Michigan sponges have repeatedly been found by the writer growing abundantly in streams receiving sewage from cities. In several such streams the original fauna has been greatly depleted. Waters receiving industrial wastes have also been found with sponge growths, occasionally quite plentiful. Sponges apparently are able to adapt themselves to an environment contaminated with organic or industrial wastes. In spite of the supposed sensitivity to anything abnormal in an environment, the sponges were growing, so far as the writer could observe, in a perfectly normal way.

GEOGRAPHICAL DISTRIBUTION OF MICHIGAN SPECIES

Spongilla aspinosa

Michigan, New Jersey, Virginia. Annandale (1916) describes a specimen from Japan as *S. aspinosa*, but it has spined flesh spicules and consequently should not be confused with Potts' species.

Spongilla lacustris

Alaska.

British Columbia, New Brunswick, James Bay, St. Lawrence River, Ottawa River, Newfoundland, Nova Scotia.

Colorado, Kansas, Illinois, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Utah, Washington, Wisconsin, Wyoming.

Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, England, Estonia, Finland, France, Germany, Holland, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Rumania, Russia, Scotland, Spain, Sweden, Switzerland, Yugoslavia.

China, Japan, India.

Cape Colony, Africa.

Australia, New Zealand.

Spongilla fragilis

British Columbia, Quebec, Newfoundland, Nova Scotia.

Colorado, Florida, Kentucky, Kansas, Illinois, Indiana, Iowa, Maine, Michigan, Minnesota, Montana, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Utah, Wisconsin, Wyoming.

Guatemala.

Brazil.

Belgium, Bulgaria, Czechoslovakia, England, Finland, France, Germany, Ireland, Poland, Rumania, Russia, Scotland, Switzerland, Siberia, China, Japan, India.

Australia.

Spongilla igloviformis

Massachusetts, Michigan, New Jersey, Wisconsin.

Trochospongilla pennsylvanica

Florida, Massachusetts, Michigan, New Hampshire, New Jersey, Ohio, Pennsylvania, Wisconsin.

Newfoundland, Nova Scotia.

Ireland (?), Scotland (?).

India.

Ephydatia crateriformis

Illinois, Indiana, Maryland, Michigan, New York, Ohio, Pennsylvania, Wisconsin.

Mexico.

Ireland (?).

China, India.

Ephydatia mülleri

British Columbia, Newfoundland, Nova Scotia.

Colorado, Illinois, Indiana, Iowa, Maryland, Massachusetts, Michigan, Montana, New Hampshire, New York, Ohio, Pennsylvania, Virginia, Wisconsin.

Austria, Belgium, Bulgaria, Czechoslovakia, England, Finland, France, Germany, Holland, Hungary, Ireland, Poland, Rumania, Russia, Scotland, Sweden, Switzerland, Yugoslavia.

China, Japan.

Ephydatia fluviatilis

British Columbia, Newfoundland, Nova Scotia.

Colorado, Florida, Illinois, Indiana, Michigan, Ohio, Pennsylvania, Wisconsin.

Mexico.

Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, England, Estonia, Finland, France, Germany, Holland, Hungary, Ireland, Italy, Latvia, Norway, Poland, Rumania, Russia, Scotland, Spain, Switzerland, Yugoslavia.

China, India, Japan, Sumatra, Syria, Turkestan.

Australia, New Zealand.

Cape Colony, Africa.

Heteromeyenia repens

Nova Scotia.

Illinois, Indiana, Michigan, New Jersey, New Hampshire, New York, Pennsylvania.

Germany, Poland.

Heteromeyenia ryderi

New Brunswick, Newfoundland, Nova Scotia.

Florida, Georgia, Indiana, Iowa, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Pennsylvania, Virginia.

Ireland, Scotland.

Heteromeyenia argyrosperma

Newfoundland.

Illinois, Indiana, Michigan, New Hampshire, New Jersey, Pennsylvania, Wisconsin.

Carterius tubisperma

California, Illinois, Indiana, Iowa, Kansas, Massachusetts, Michigan, New York, Ohio, Wisconsin.

DISCUSSION

The geographical distribution of fresh-water sponges is a wide one, although there are still many parts of the world which have not been examined for them. Most of the information concerning distribution comes from casual and scattered collections rather than from extensive examinations of a particular area. The sponge faunas of Europe and India are apparently better known than those of other regions, but even there only limited areas have been examined. All other geographic regions are as yet relatively unknown. So far, only the Malay Peninsula (Dover, 1929) is definitely reported to be entirely devoid of fresh-water sponges.

Some species are apparently cosmopolitan in their range, others, so far as is known, are discontinuous in their range, or limited to one or more land areas. This limitation may be due to a condition suggesting an inability of certain species to become abundant even in waters apparently suitable to them, and consequently the probability of becoming disseminated is low.

Records of the Michigan species of fresh-water sponges and of the major divisions of the world from which they have been reported in various scientific publications are indicated in Table II.

TABLE II

RECORDS OF THE OCCURRENCE OF MICHIGAN SPECIES OF FRESH-WATER
SPONGES IN VARIOUS PARTS OF THE WORLD

	<i>S. aspinosa</i>	<i>S. lacustris</i>	<i>S. fragilis</i>	<i>S. igloviformis</i>	<i>T. pennsylvanica</i>	<i>E. crateriformis</i>	<i>E. mülleri</i>	<i>E. fluviatilis</i>	<i>H. repens</i>	<i>H. ryderi</i>	<i>H. argyrosperma</i>	<i>C. tubisperma</i>
North America	+	+	+	+	+	+	+	+	+	+	+	+
Central America			+									
South America			+									
British Isles		+	+		(?)	(?)	+	+		+		
Europe		+	+				+	+	+			
Africa		+						+				
Asia		+	+		+	+	+	+				
Australia		+	+					+				

Questionable locality records

T. pennsylvanica and *E. crateriformis*, originally reported from Ireland by Hanitsch (Stephens, 1920), were reëxamined by Stephens, who decided that both were forms of *H. ryderi*, which is very abundant in Ireland. Specimens of *T. pennsylvanica* and *E. crateriformis* were searched for by Stephens, but never found. Annandale (1909) found *T. pennsylvanica* in Scotland, but re-examination by Stephens showed that it "was undoubtedly the lake form of *H. ryderi*." Consequently, records of these two species from Ireland and one from Scotland should probably be expunged. Pending additional information concerning these forms, the writer has continued to use them under the originally proposed names, but indicates the uncertainty involved in both cases.

SUMMARY

1. The list of sponges of Michigan includes twelve species: *Spongilla aspinosa*, *S. lacustris*, *S. fragilis*, *S. igloviformis*, *Tro-*

chospongilla pennsylvanica, *Ephydatia crateriformis*, *E. mülleri*, *E. fluviatilis*, *Heteromeyenia repens*, *H. ryderi*, *H. argyrosperma* and *Carterius tubisperma*.

2. Generic and specific identification of sponges by external features is not practicable. Branched colonies among the various species are more common than had been expected, and branched forms as well as unbranched ones of the same species occur in the same environment.

3. Identification of sponges by odor is of little value beyond the possibility of recognizing as sponges those colonies which are disguised by unusual appearance or by extraneous materials.

4. Gemmules are produced by sponges during the favorable season as well as near its close. Sponges with gemmules were found as early as the last week in June and were common by the first week in July.

5. The taxonomic description of each species has been made more nearly complete; it comprises a composite made up as a total of all characters assembled from all specimens collected.

6. All known locality records for the sponges of Michigan have been assembled, including their distribution in the major divisions of the world.

7. The best collecting grounds in Michigan were found in the Upper Peninsula in waters free from the influences of man.

8. Luxuriant growths of sponges are not limited to any particular point in a stream draining a lake or to rapidly flowing streams. Such growths are as likely to occur in standing waters or in flowing waters not connected with lakes.

9. Contrary to statements in the literature, sponges occur in sluggish streams and shallow ponds, where they may grow even on the soft mud bottom; highly colored waters also contain sponges.

10. Sponges may grow in a perfectly normal condition in waters contaminated by industrial and organic wastes.

ACKNOWLEDGMENTS

The author is especially indebted to Professor Paul S. Welch, under whom this work was conducted. Acknowledgments are

due also to Professor George R. La Rue for the use of facilities at the University of Michigan Biological Station; to many associates who have given valuable aid; and to Professor Frank Smith for reading the manuscript and offering constructive suggestions.

URSINUS COLLEGE
COLLEGEVILLE, PA.

LITERATURE

- ADAMS, C. C. 1908. An Ecological Survey of Isle Royale, Lake Superior. Published as part of the Report of the Board of Geological Survey for 1908, pp. 249-250.
- ANNANDALE, N. 1908. Notes on Some Freshwater Sponges in Scotland. *Journ. Linn. Soc.*, 30: 244-250.
- 1909. Fresh-Water Sponges in the Collection of the U. S. National Museum. *Proc. U. S. Nat. Mus.*, 37: 401-406.
- 1909a. Beiträge zur Kenntnis der Fauna von Süd-Africa. *Zool. Jahrb., Abt. f. Syst.*, 27: 559-568.
- 1911. Freshwater Sponges, Hydroids and Polyzoa. *Fauna of British India*, London, 251 p.
- 1919. Sponges, Hydrozoa and Polyzoa of Seistan. *Rec. Ind. Mus.*, 18: 83-89.
- AND KAWAMURA, T. 1916. The Sponges of Lake Biwa. *Journ. College Sci., Imp. Univ. Tokyo*, 39: 1-27.
- ARNDT, W. 1926. Die Spongillidenfauna Europas. *Archiv f. Hydrobiol.*, 17: 337-365.
- 1928. Die Süßwasserschwamm *Heteromeyenia ryderi* Potts auf den Fär Öern. *Zool. Anz.*, 77: 156-166.
- 1928a. Porifera, Schwämme, Spongien. *Die Tierwelt Deutschlands*, Jena, 4: 1-94.
- BISHOP, S. C., AND CLARKE, N. T. 1922. A Scientific Survey of Turner's Lake, Isle-au-Haut, Maine. *New York State Museum*, 29 p.
- CARPENTER, KATHLEEN E. 1928. *Life in Inland Waters*. New York, 267 p.
- CRAWSHAY, L. R. 1915. A Method of Separating Sponge Spicules by Filtration. *Journ. Marine Biol. Assn.*, 10: 590-591.
- CROWELL, M. F. 1926. Notes on Gemmules and Spicules of *Heteromeyenia ryderi* Potts. *Occas. Pap. Boston Soc. Nat. Hist.*, 5: 203-206.
- DOVER, C. 1929. Fresh Water Fauna of the Malay Peninsula. *Nature*, 124: 497-500.

- DUNCAN, P. M. 1881. On Some Remarkable Enlargements of the Axial Canals of Sponge Spicules and Their Causes. *Journ. Roy. Microsc. Soc.*, 1: 557-572.
- GARBINI, A. 1894. Contributo allo studio delle spongille italiane. *Acad. Agri. Art. Comm.*, 70: 1-23.
- GEE, N. GIST. 1927. Chinese Fresh-water Sponges. *Lingnaam Agric. Rev.*, 4: 1-10.
- AND WU, C. F. 1927a. Chinese Fresh Water Sponges. *Bull. Peking Soc. Nat. Hist.*, 2: 1-14.
- GELEI, J. VON. 1929. Einiges über die Variabilität von *Spongilla fragilis* (Leidy), zugleich Beiträge zur Biologie des Tieres. *Intern. Rev. gesamt. Hydrobiol. u. Hydrograph.*, 22: 157-178.
- HANKINSON, T. L. 1916. Observations on the Fishes of Houghton County, Michigan. *Mich. Geol. and Biol. Surv.*, Publ. 20, Ser. 4, pp. 11-24.
- 1916a. Results of the Shiras Expedition to Whitefish Point, Michigan: Fishes. *Ibid.*, pp. 109-160.
- HAY, W. P. 1903. Observations on the Crustacean Fauna of the Region about Mammoth Cave, Kentucky. *Proc. U. S. Nat. Mus.*, 25: 223-236.
- JEWELL, MINNA E., and BROWN, H. W. 1929. Studies on Northern Michigan Bog Lakes. *Ecology*, 10: 427-475.
- KIRKPATRICK, R. 1907. Notes on Two Species of African Freshwater Sponges. *Ann. Mag. Nat. Hist.*, 20: 523-525.
- LENDENFELD, R. VON. 1887. Die Süßwasser-Coelenteraten Australiens. *Zool. Jahrb., Syst. Geog. u. Biol.*, 2: 87-108.
- 1904. Über die Herstellung von Nadelpräparaten von Kieselschwämmen. *Zeitsch. wissenschaft. mikro. u. mikro. Tech.*, 21: 23-24.
- MACKAY, A. H. 1889. Fresh-water Sponges of Canada and Newfoundland. *Trans. Roy. Soc. Can.*, 7: 85-95.
- MEEK, S. E. 1905. The Zoology of Lake Amatitlan and Atitlan, Guatemala, with Special Reference to Ichthyology. *Field Columb. Mus. Publ. Zool.*, 7: 159-206.
- MORGAN, ANN H. 1930. *Field Book of Ponds and Streams*. New York, 448 p.
- MÜLLER, K. 1911. Über eine vermutliche Varietät von *Ephydatia fluviatilis*. *Zool. Anz.*, 38: 495-500.
- POTTS, E. 1884. Some Modifications Observed in the Form of Sponge Spicules. *Proc. Acad. Nat. Sci. Phila.*, pp. 184-185.
- 1887. Fresh Water Sponges. A Monograph. *Proc. Acad. Nat. Sci. Phila.*
- 1918. The Sponges (Porifera). In Ward and Whipple, "Fresh-water Biology," New York, 1111 p.

- RESVOJ, P. 1926. Einige Angaben über die Süßwasserschwämme des Oka-Flusses. Arb. Biol. Oka-Station (Murom Russland), 4: 64.
- SCHRÖDER, K. 1926. Carterius stepanowi (Dyb.) im Osten Deutschlands. Zugleich ein Überblick über die Süßwasserschwammfauna Schlesiens. Zool. Anz., 67: 240-250.
- 1927. Spongillidenstudien II, über das Vorkommen von Heteromeyenia repens Potts in Deutschlands. *Ibid.*, 70: 75-82.
- 1927a. Über die Gattungen Carterius Petr, Astromeyenia Annandale, und Heteromeyenia Potts. Spongilliden-Studien III. *Ibid.*, 73: 101-112.
- SCHULZE, P. 1923. Beiträge zur Kenntnis der Kieselnadelbildung besonders bei den Spongilliden. Archiv f. Zellforsch., 17: 105-130.
- SMITH, F. 1921. Data on the Distribution of Michigan Fresh-water Sponges. Pap. Mich. Acad. Sci. Arts and Letters, 1: 418-421.
- 1921a. Distribution of the Fresh-water Sponges of North America. Illinois Dept. Reg. Educ., Div. Nat. Hist. Surv., 14: 9-22.
- 1930. Some Recent Collections of Canadian Fresh-water Sponges. Canadian Field Nat., 44: 182-185.
- AND GREEN, B. R. 1915. The Porifera, Oligochaeta, and Certain Groups of Invertebrates in the Vicinity of Douglas Lake, Michigan. Ann. Rep. Mich. Acad. Sci., 17: 81-84.
- STEPHENS, JANE. 1920. The Freshwater Sponges of Ireland. Proc. Roy. Irish Acad., 35: 205-254.
- TOPSENT, E. 1893. Note sur la faune des Spongillides de France. Bull. Soc. Zool., 18: 172-182.
- VAN TRIGT, H. 1919. A Contribution to the Physiology of the Fresh-water Sponges (Spongillidae). Leiden, 220 p.
- WELTNER, W. 1893. Spongillidenstudien II. Arch. f. Naturgesch., 59: 245-284.
- 1895. Spongillidenstudien III. Arch. f. Naturgesch., 61: 114-144.
- 1909. Spongillidae, Süßwasserschwämme. Die Süßwasserfauna Deutschlands, 19: 177-190.
- 1910. Spongillidae. Die Fauna Südwest-Australiens, 3: 137-144.
- 1911. Beiträge zur Kenntnis der Fauna Turkestans. Spongillidae des Issyk-Kul-Sees und des Baches bei Dschety-Ogus. Trav. Soc. Imp. Natural., 42: 59-76.
- 1913. Süßwasserschwämme (Spongillidae) der deutschen Zentralafrika-Expedition. 1907-1908. Leipzig.
- WIERZEJSKI, A. 1912. Über Abnormitäten bei Spongilliden. Zool. Anz., 39: 290-295.

PLATE XXXVII



FIG. 9

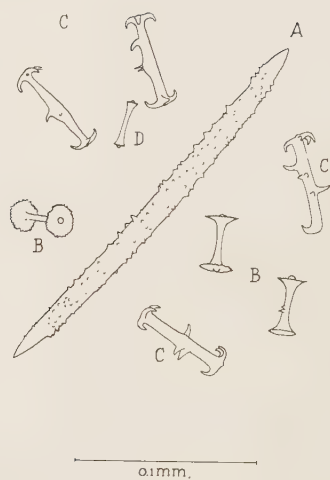


FIG. 10

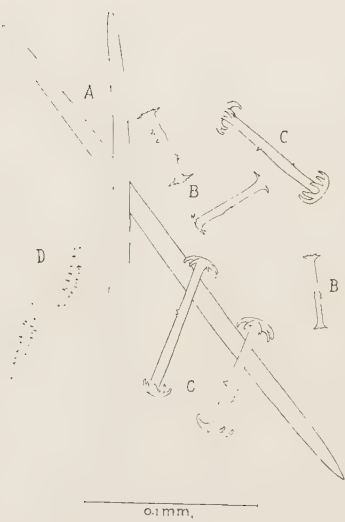


FIG. 11

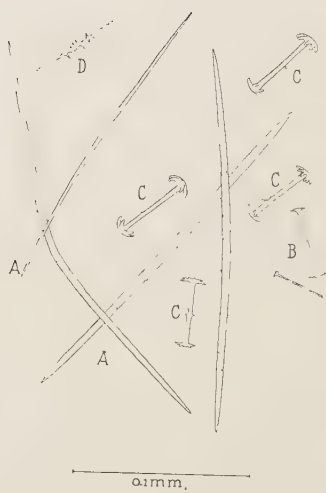


FIG. 12

PLATE XXXVI



FIG. 5

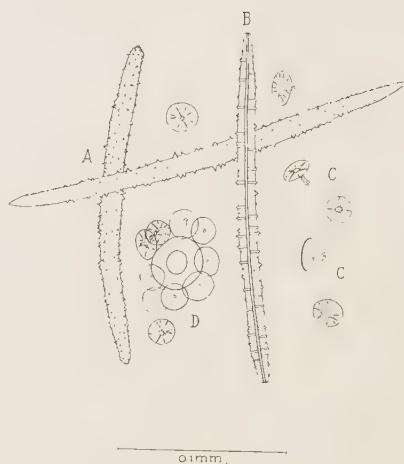


FIG. 6



FIG. 7

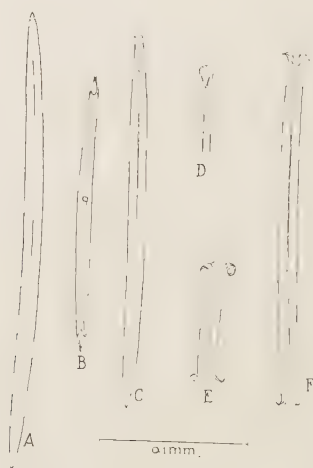


FIG. 8

PLATE XXXV



FIG. 1

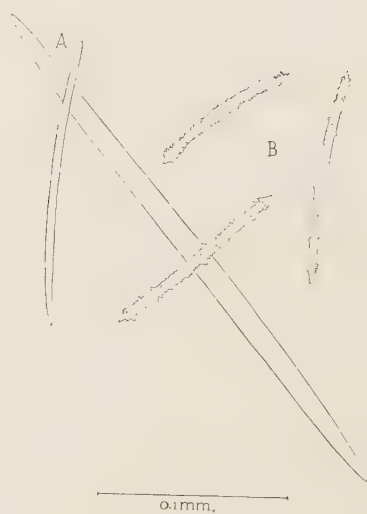


FIG. 2



FIG. 3



FIG. 4

EXPLANATION OF PLATES XXXV-XXXVII

(Drawings made with the aid of a camera lucida)

PLATE XXXV

- FIG. 1. *Spongilla fragilis*. — *A*, skeleton spicules; *B*, gemmule spicules; *C*, gemmule spicule with axial and subaxial canals
- FIG. 2. *S. fragilis*. — *A*, skeleton spicules; *B*, gemmule spicules
- FIG. 3. *S. fragilis*. — *A*, skeleton spicules; *B*, gemmule spicules; *C*, abnormal gemmule spicules
- FIG. 4. *S. fragilis*. — *A*, skeleton spicules; *B*, gemmule spicules; *C*, abnormal skeleton spicules

PLATE XXXVI

- FIG. 5. *Ephydatia mülleri*. — *A*, skeleton spicules; *B*, abnormal gemmule spicules
- FIG. 6. *Trochospongilla pennsylvanica*. — *A*, skeleton spicules; *B*, skeleton spicule with axial and subaxial canals; *C*, gemmule spicules; *D*, portion of surface of gemmule showing arrangement of the two kinds of unequal birotulates around the sunken foramen
- FIG. 7. *T. pennsylvanica*. — *A*, skeleton spicules; *C*, gemmule spicules
- FIG. 8. Sponge unknown. — *A-F*, skeleton spicules; for explanation see page 453.

PLATE XXXVII

- FIG. 9. *Heteromeyenia ryderi*. — *A*, skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, end view of *B*
- FIG. 10. *H. ryderi*. — *A*, skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, immature gemmule spicule of shorter class
- FIG. 11. *H. repens*. — *A*, smooth skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, flesh spicules
- FIG. 12. *H. repens*. — *A*, sparsely spined skeleton spicules; *B*, gemmule spicules of shorter class; *C*, gemmule spicules of longer class; *D*, flesh spicule

ENVIRONMENTAL SELECTION OF THE FRESH-WATER SPONGES (SPONGILLIDAE) OF MICHIGAN*

M. C. OLD

Ursinus College, Collegeville, Pennsylvania

INTRODUCTION

The literature contains no reference to work that is concerned with an environmental study of fresh-water sponges. Arndt (1926), reviewing the literature, states that the ecological factors upon which the European sponges are dependent have so far been neglected. Stephens (1920) working in Ireland has noticed that *Heteromeyenya ryderi* shuns direct light by restricting itself to the underside of objects, also that *H. repens*, *Spongilla lacustris* and *Ephydatia fluviatilis* are lime-shunning forms. Other workers have depicted sponge habitats from single or few collections with consequent rather narrow and unsatisfactory descriptions.

Believing that a worthy contribution could profitably be made along these lines, an extensive study of sponge habitats was undertaken by selecting four major groups of data: (1) general information concerning the body of water, (2) physical conditions, (3) chemical conditions, and (4) biological conditions. Under the head of general information were included the kind of body of water; soil, slope, and any artificiality on the land adjacent to the water; windswept or protected condition; probable pollution; and the presence of inlet and outlet. Under physical conditions special emphasis was laid upon molar agents, turbidity, color, odor, temperature, nature of movement of water, light exposure, denseness of bottom, and presence of gases in bottom. The chemical conditions taken into consideration were pH, CO₂, carbonates, bicarbonates, total and temporary hardness. The kind of support of the sponge in the various waters, the common macroscopic plants and animals present, the depths at which the sponges were found, and the presence of refuse of diverse kinds were noted as biological conditions.

An environmental study of this kind should be valuable due to the *apparent extreme sensitivity* of fresh-water sponges. The general opinion of workers (although none mention it directly), as gleaned from the literature, is that sponges are very sensitive to alterations in their environment. The experience of the writer in attempts to culture sponges in the laboratory also seemed to point to a high selectivity. On account of the unusual diversity of Michigan waters, namely, acid and alkaline bogs, and acid, alkaline, and neutral lakes and streams, they seemed to offer an excellent opportunity for a study of habitat selection and sponge resistance. The actual study of habitats was begun June 26, 1929, and continued through the summer to October 19,

* Contribution from the Biological Station and the Zoological Laboratory of the University of Michigan.

covering every county in the state. Every effort was made to avoid any conscious selection of habitats. All waters were examined at every opportunity, for only by so doing could satisfactory conclusions be reached.

This study also yielded material for a paper on the taxonomy and distribution of fresh-water sponges of Michigan (Old, 1931). Another section dealing with the biology of fresh-water sponges, representing also earlier work, is in press.

The author is especially indebted to Professor Paul S. Welch under whom this work was conducted. Acknowledgments are also due Professor George R. LaRue for the use of facilities at the University of Michigan Biological Station.

METHODS

For the determination of the physical and chemical conditions of each habitat, the methods outlined in the Standard Methods of Water Analysis, 6th edition, were employed. The hydrogen ion concentration was measured by means of a standard colorimeter prepared by the LaMotte Chemical Products Company, covering a pH range of 3.0 to 9.6. Hardness of the water was estimated by the use of the soap method. Temperature records were obtained with a maximum and minimum thermometer; turbidity, by the use of the U.S.G.S. Turbidity Rod; and color, by the use of the U.S.G.S. Field Apparatus for measuring color of water. Both hot and cold odor tests were made.

Velocity of streams was measured by means of a simple glass tube bent at right angles. Height of the column of water in the vertical portion of the tube above the general water level is dependent upon the velocity of the water passing into the horizontal portion of the tube. Height of the water column in feet minus the extent of capillarity (determined by dipping the vertical end into the water and measuring the rise of the water) substituted for h in the formula $V=0.977\sqrt{2gh}$, where g represents the acceleration due to gravity (32.16), gives the velocity of the water in feet per second.

A total of 145 sponge habitats were examined, scattered over every major part of Michigan. Due to (1) the necessity of completing this survey in the allotted time; (2) the time consumed in making complete environmental analyses; (3) occasional almost insurmountable physical difficulties involved in reaching sponge supporting waters with the equipment; and (4) the desire to obtain as many records of the distribution of Michigan species as possible, some sponge habitat analysis had to be either omitted or analyzed incompletely. However, practically all were examined for the more obvious general, physical, and biological conditions, but chemical analyses are lacking for 39 habitats.

PROPOSED OPTIMUM HABITATS

From tables containing summaries of data from all sources for all species, it appears that certain optimum conditions prevail. An apparently optimum habitat is described for each by noting conditions in which the frequency of each species of sponges was greatest. *Spongilla aspinosa* Potts, *S. iglovisformis* Potts, and *Ephydatia crateriformis* (Potts), although found to occur in Michigan, are not so treated since results for them are too meager.

It seems reasonable to expect that the fresh-water sponges with such a diversity of genera and species would show a certain differential habitat selection. The writer is well aware of the fact that a completely exhaustive analysis of these various habitats has not been made; that it may be that some existing influential conditions have not yet been discovered or, if known, have had inadequate study; and that the limits proposed for any condition or group of conditions may be exceeded in some other part of the range of the species involved. However, it is hoped, that these attempts to formulate a statement of the structure of the optimum habitats will serve to correct a considerable number of erroneous statements in the literature and perhaps function as a basis on which future progress in this particular field may be built. This is the first attempt to make this type of study, and without doubt will be subject to future revision.

The purpose of these optimum habitats was to formulate, from the accumulated data, the environmental complex preferred by the different species. They were composed by noting the conditions under which the highest frequency of occurrence was found. No claim is made that the list is complete, but it is believed that it includes a large portion of the salient factors that make up a suitable environment.

Spongilla lacustris AUCTORUM

General and physical conditions: lakes and smooth streams open to sunlight; bottom soil, sand, gravel, or rock, with organic deposits; slope of adjacent land, pronounced to gradual; surroundings natural; shore wind-swept or protected. Water: pollution absent; turbidity, less than 20; color, below 80; earthy, grassy odor; summer temperatures, 61–75° F.

Chemical conditions: pH, 7.1–8.0; free CO₂, 0–6 p.p.m.; phenolphthalein alkalinity, 0–2 p.p.m. CaCO₃; methyl orange alkalinity, 90–170 p.p.m. CaCO₃; total hardness, 60–140 p.p.m. CaCO₃; temporary hardness, 0–20 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; floating plants absent; refuse lacking; support of sponges in lakes, wood and vegetation; in streams, wood and rocks; sponge depth in water, 1–12 inches.

Spongilla fragilis LEIDY

General and physical conditions: ponds, lakes, and smooth streams, open to sunlight; bottom soil, sand, gravel, or rock, with organic deposits; slope of adjacent land, pronounced to gradual; surroundings natural. Water: pollution absent; turbidity, less than 20; color below 100; earthy, grassy odor; summer temperatures, 61–75° F.

Chemical conditions: pH, 7.1–8.0; free CO₂, 0–12 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 50–170 p.p.m. CaCO₃; total hardness, 40–200 or more p.p.m. CaCO₃; temporary hardness, 0–30 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; wood refuse present or absent; support of sponges, wood; depth, 1–12 inches.

Trochospongilla pennsylvanica (POTTS)

General and physical conditions: lakes and smooth streams, open to sunlight; bottom soil, sand, gravel, or rock, with organic deposits; slope of adjacent land, pronounced; surroundings natural or artificial. Water: pollution absent; color, 160–180; earthy, grassy odor; summer temperatures, 66–70° F.

Chemical conditions: pH, 6.1–7.0; free CO₂, 0.5–3 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 30–50 p.p.m. CaCO₃; total hardness, 40–80 p.p.m. CaCO₃; temporary hardness, 1–10 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; wood refuse present or absent; support of sponges, wood; depth, 1–12 inches.

Ephydatia fluviatilis (AUCTORUM)

General and physical conditions: smooth streams, shaded; bottom soil, sand, gravel, rock, with or without organic deposits; slope of adjacent land, gradual to insignificant; surroundings, natural or artificial. Water: pollution present; turbidity, less than 20; color, 40–100; odor, grassy or none; summer temperatures, 51–60° F.

Chemical conditions: pH, 7.1–8.0; free CO₂, 6.5–9 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 150–230 p.p.m. CaCO₃; total hardness, 140–180 p.p.m. CaCO₃; temporary hardness, 0–30 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; no refuse; support of sponges, wood; depth, 1–12 inches.

Ephydatia mülleri (LIEBERKÜHN)

General and physical conditions: smooth streams, open to sunlight; bottom soil, sand and gravel, with or without organic deposits; slope of adjacent land, pronounced to gradual; surroundings, natural. Water: pollution absent;

turbidity, 7 or less; color 20-80; earthy, grassy, musty odor; summer temperatures, 61-75° F.

Chemical conditions: pH, 7.1-8.0; free CO₂, 0-6 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 150-210 p.p.m. CaCO₃; total hardness, 60-160 p.p.m. CaCO₃; temporary hardness, 0-40 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; wood refuse present or absent; support of sponges, wood and rocks; depth, 1-12 inches.

Heteromeyenia repens POTTS

General and physical conditions: ponds, open to sunlight; bottom soil, sand, with organic deposits; slope of adjacent land, gradual; surroundings natural. Water: pollution absent; color, 20-60; odor, earthy, grassy, or musty; summer temperatures, 61-75° F.

Chemical conditions: pH, 6.0-7.5; free CO₂, 3.5-15 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 30-110 p.p.m. CaCO₃; total hardness, 40-100 p.p.m. CaCO₃; temporary hardness, 0-10 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; no refuse; support of sponges, wood, rocks, or vegetation; depth, 1-12 inches.

Heteromeyenia ryderi POTTS

General and physical conditions: lakes and smooth streams, open or shaded to sunlight; bottom soil, sand with organic deposits; slope of adjacent land, pronounced to gradual; surroundings natural. Water: pollution absent; turbidity, 7 or less; color 20-60; odor, grassy, earthy, moldy; summer temperatures, 66-80° F.

Chemical conditions: pH, 6.6-8.0; free CO₂, 3.5-12 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 30-130 p.p.m. CaCO₃; total hardness, 40-80 p.p.m. CaCO₃; temporary hardness, 10-30 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; with or without duckweeds; wood refuse or no refuse; support of sponges, wood; depth 1-12 inches.

Heteromeyenia argyrosperma POTTS

General and physical conditions: ponds, lakes, or streams, open to sunlight; bottom soil, sand, gravel, or rock, with organic deposits; slope of adjacent land, pronounced to insignificant; surroundings natural. Water: pollution absent; turbidity, less than 20; color, 60-80; odor, grassy; summer temperatures, 66-70° F.

Chemical conditions: pH, 6.1-7.0; free CO₂, 0.5-9 p.p.m.; phenolphthalein alkalinity, 0; methyl orange alkalinity, 19-50 p.p.m. CaCO₃; total hardness, 40-80 p.p.m. CaCO₃; temporary hardness, 0-10 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; no refuse; support of sponges, wood or rocks; depth 1-12 inches.

Carterius tubisperma MILLS

General and physical conditions: smooth streams, open or partially shaded to sunlight; bottom soil, sand, gravel, or rock, with organic deposits; slope of adjacent land, pronounced to gradual; surroundings natural. Water: pollution, present or absent; turbidity, less than 20; color, 40-80; odor, earthy, grassy, musty; summer temperatures, 56-80° F.

Chemical conditions: pH, 7.1-8.0; free CO₂, 0-12 p.p.m.; phenolphthalein alkalinity, 0-2 p.p.m. CaCO₃; methyl orange alkalinity, 110-170 p.p.m. CaCO₃; total hardness, 80-200 or more p.p.m. CaCO₃; temporary hardness, 0-20 p.p.m. CaCO₃.

Biological conditions: common aquatic animals and plants present; no floating plants; wood refuse or none; support of sponges, wood, rocks, or vegetation; depth, 1-12 inches.

DISCUSSION

The total habitats, distributed among 19 ponds, 42 lakes, and 84 streams, yielded 538 specimens of sponges. Whether the numbers represent accurately the numerical relations of ponds, lakes, and streams of Michigan cannot be stated with any certainty. It can only be hoped that the sum total of collections is reasonably representative of the habitats at large. Since the number of ponds and lakes is decidedly less than the number of streams, it would follow that any species with a higher frequency of occurrence in ponds or lakes necessarily favors ponds or lakes. *S. lacustris*, *T. pennsylvanica*, *H. ryderi*, and *H. argyrosperma* may then be said to favor lakes, and *H. repens* ponds. *S. fragilis* appears to inhabit equally well ponds, lakes, or streams. *E. mülleri*, *E. fluviatilis*, and *C. tubisperma* apparently favor streams.

All the species seem to prefer wood as a base of attachment for growth, with probably the exception of *E. mülleri* and *S. lacustris* which were found growing, in streams, as frequently on rocks as on wood. This may be due to a paucity of wood and an abundance of rocks. However, substitution of other supporting substances is very common.

It is interesting to note that only one species, *E. fluviatilis*, was found exclusively in waters under shaded or partially shaded conditions. *T. pennsylvanica* and *H. ryderi*, although preferring the underside of objects, apparently occur most frequently in waters exposed to the sun.

Evidently the nature of the land surrounding waters is of no direct consequence as far as limiting the presence of sponges. Data concerning the kind of soil, and the amount of slope reveal nothing significant. The members of the genus *Heteromeyenia*, however, are ruled out by the presence of some

artificial influence, notably pollution. Presence or absence of inlets and outlets of lakes is, in general, immaterial. Protected waters appeared to be preferred, but windswept shores are not ruled out.

Low turbidity is the usual case, but turbidities up to 35 p.p.m. silica may be tolerated. Low color values exist in a plurality of habitats, but color values above 120 p.p.m. platinum seem to be associated with the absence only of *E. mülleri* and *E. fluviatilis*. A cold odor of earthy, grassy, musty, and moldy seems to be the general rule, with the possibility that sour, putrid, or disagreeable odors may result from conditions which rule out certain species as *H. repens*, *H. ryderi*, and *H. argyrosperma*.

The summer temperatures vary from 51–90° F. *T. pennsylvanica*, *H. repens*, *H. ryderi*, and *H. argyrosperma* were not found at the colder temperatures, 51–60° F., neither were they found at temperatures above 80° F. This may further aid one to understand their evident scarcity. One species, *E. fluviatilis*, appears to occur at low as well as high temperatures. It is interesting to note that no sponges were found in the cold trout streams. Probably as many as forty or more such streams were examined without finding a single specimen.

Sponges were repeatedly found growing in waters receiving organic and industrial wastes. In several such streams the original fauna has been greatly depleted, but, as far as the writer could observe, sponges were growing in a perfectly normal way. *Ephydatia fluviatilis* was found most frequently in polluted waters.

The velocity of streams examined varied from 0.25–4.0 feet per second, and *S. fragilis* was the most common inhabitant. The only species actually ruled out by rapids are *T. pennsylvanica*, *H. repens*, and *H. ryderi*.

Soil, organic materials, gaseous condition, and denseness of the bottom, as they occur in sponge habitats, seem to have little influence.

Macroscopic aquatic animals and plants may be present or absent; even filamentous algae, a supposed natural enemy of sponges (Annandale, '11), may be present in large numbers. Most sponges were found in the littoral zone of waters, where it is relatively shallow, and which is considered the richest zone of animal and plant life.

The hydrogen ion concentration variation of the different habitats was found to be 4.2–9.2. Only *S. fragilis* tolerated the entire range; 8.6–9.0 includes *S. fragilis* and *S. lacustris*; 8.1–8.5, *S. fragilis*, *S. lacustris*, *T. pennsylvanica*, *E. mülleri*, and *C. tubisperma*; 7.6–8.0, all but *H. argyrosperma*; 7.1–7.5, all species; 6.6–7.0 is correlated with the absence of *E. fluviatilis*; 6.1–6.5 further correlated with the absence of *E. fluviatilis* and *C. tubisperma*; 4.2–6.0, correlated with absence of *S. lacustris*, *E. mülleri*, *E. fluviatilis*, and *C. tubisperma*. There is a suggestion of a preference for alkaline waters by *S. lacustris*, *S. fragilis*, *E. mülleri*, *E. fluviatilis*, and *C. tubisperma*, and

preference for acid waters by *T. pennsylvanica*, *H. repens*, *H. ryderi*, and *H. argyrosperma*.

It appears that sponges may be found in waters with a free CO_2 content of 0-33 p.p.m. Phenolphthalein alkalinity may vary from 0-22 p.p.m. CaCO_3 , with an optimum of zero for all species. Not only are *H. ryderi*, *S. lacustris*, and *E. fluvialis* "lime-shunning forms" (Stephens, '20) but all the Michigan species seem to prefer waters of zero carbonate content. The methyl orange alkalinity varies from 19-270 p.p.m. CaCO_3 , with a wide optimum around 31-200 p.p.m. CaCO_3 , with the exception of *H. argyrosperma* which was limited to waters of low methyl orange alkalinity.

Total hardness in p.p.m. CaCO_3 varies from 1-200 plus, with the optimum, 41-200 plus, but again it is *H. argyrosperma* that is limited to a low total hardness. Low temporary hardness, as can be expected from related chemical data, is only limiting to *T. pennsylvanica*, *H. repens*, *H. ryderi*, and *H. argyrosperma*.

CONCLUSION

It is apparent that no single index condition accounts for the habitat distribution of Michigan species of fresh-water sponges, but rather a sum of multiple influences. It was expected that sponges, seemingly very sensitive in the laboratory, would manifest high selectivity of habitats in nature. However, this expectation has not been fully realized, since this investigation has shown them to be, as a group, tolerant of a rather wide range of general conditions. The supposed sensitivity in the laboratory, therefore, seems to call for some other explanation.

LITERATURE CITED

- Annandale N. 1911. Freshwater Sponges, Hydroids and Polyzoa. Fauna of British India, London, 251 pp.
- Arndt, W. 1926. Die Spongillidenfauna Europas. Archiv. f. Hydrobiol. 17:337-365.
- Old, Marcus C. 1931. Taxonomy and Distribution of the Fresh-water Sponges (Spongillidae) of Michigan. Papers Mich. Acad. Sci., Arts and Letters, 15:439-477.
- Stephens, Jane, 1920. The Freshwater Sponges of Ireland. Proc. Roy. Irish Acad. 35:205-254.

CONTRIBUTION TO THE BIOLOGY OF FRESH-WATER SPONGES (SPONGILLIDAE) *

MARCUS C. OLD

I. FIELD OBSERVATIONS ON GROWTH

THE literature on fresh-water sponges contains statements that they disintegrate with the onset of unfavorable conditions in the fall and that they then liberate their gemmules, which are spread by slowly sinking or drifting to new places. Thus any growth would be of one season only. These statements are badly in need of verification, since they appear to be largely inferential. The investigation described below was carried out in an attempt to extend our knowledge of seasonal growth.

METHODS

Bessey Creek, Douglas Lake, Michigan, contains many colonies of sponges which are unusually large during the summer season. This habitat seemed a good one in which to find out whether these sponges represent one season's growth, and if not, how much is the growth of a single season. Since many colonies are spindle-shaped, coating slender twigs and branches, measurements of maximum length and thickness were easily made, and a marker for the sponge was attached. Each marker consisted of a small square of sheet copper on which was stamped a letter or number. Two lengths of copper wire fastened to the sides of the marker were then tightly wound around the branch, or other supporting object, exactly at the ends of the sponge. During three

* Contribution from the Biological Station and the Zoölogical Laboratory of the University of Michigan.

successive years sponges were marked in the fall and recovered the following summer.

RESULTS

Tables I and II give the data on experiments made in Bessey Creek during the period from 1926 to 1929. All the sponges tagged were identified on recovery as *Ephydatia mülleri* (Lieberkühn).

On June 27, 1929, a specimen of *Spongilla fragilis* Leidy, twenty-four inches in total length and three inches in its greatest width, was found in a small, shallow, temporary pond near Ann Arbor, Michigan. It was a beautiful green specimen, which coated a fallen twig and rested on the bottom of the pond in about twelve inches of water. Closer examination revealed that the living part was really only one-eighth to one-half inch thick; the remaining part consisted of dark, dead tissues that contained very many gemmules. The specimen evidently remained intact and grew larger each year by accretions on the old body. In August of 1929 this pond became totally dry; it accumulated waters again by the latter part of October and was frozen during the winter. On March 27, 1930, growing sponges were again found in the pond.

DISCUSSION

The condition of the colonies when retrieved, together with the fact that many were lost, suggests that Bessey Creek is subject to severe ice action. Only approximately 60 per cent of the sponges tagged were recovered, and of these many were in a ragged, broken condition, and with over all dimensions smaller than when tagged. There were a few, however, that had escaped injury and showed a decided increase in size by the following year. Apparently, *E. mülleri* may remain intact and build anew on the old structure as soon as conditions permit. Figure 76 is a photograph of a specimen tagged in August, 1927, and recovered in August, 1928. The increase in size during the favorable season was at least 13 cm. in length and 4.5 cm. in total thickness. *S. fragilis* apparently also remains intact and increases in size each year by growths on the surface of the old body.

VOLUME OF NEW GROWTH

A notion of the volume of new growth each season may be computed by assuming a spindle-shaped colony to approximate the volume of two similar cones placed base to base. Then the



FIG. 76. Sponge A of Table I, tagged on August 16, 1927

volume of a sponge on one date less the volume of the same sponge on a preceding date gives the volume of new growth during the interval. From the computations it may be seen that sponge A, for example, had on August 16, 1927, a volume of 176.9 c. c.; on June 22, 1928, of 158.3 c. c.; and on August 10, 1928, of 918.6 c. c.

TABLE I

I. SPONGES TAGGED ON AUGUST 10, 1926

No.	Measurements when tagged	Date recovered	Measurements at recovery	Growth
5	42 cm. $\times$ 2 cm.*	.....	.....	.....
6	29 cm. $\times$ 9 cm.	Aug. 11, 1927	44 cm. $\times$ 16 cm.	15 cm. in length 7 cm. in width
7	9 cm. $\times$ 4 cm.*	.....	.....	.....
8	22.5 cm. $\times$ 4.5 cm.	do.	35 cm. $\times$ 13 cm.	12.5 cm. in length 8.5 cm. in width
9	23 cm. $\times$ 4.5 cm.*	.....	.....	.....
10	23 cm. $\times$ 5 cm.	do.	25.5 cm. $\times$ 6.5 cm.	2.5 cm. in length 1.5 cm. in width
11	9 cm. $\times$ 6 cm.*	.....	.....	.....

II. SPONGES TAGGED ON AUGUST 16, 1927

A	16 cm. $\times$ 6.5 cm.	June 22, 1928	20 cm. $\times$ 5.5 cm.	4 cm. in length Lost 1 cm. in width
		Aug. 10, 1928	29 cm. $\times$ 11 cm.	13 cm. in length 5.5 cm. in width
B	26 cm. $\times$ 6.5 cm.*	.....	.....	.....
C	21 cm. $\times$ 3.5 cm.	June 22, 1928	21 cm. $\times$ 2 cm.	Lost 1.5 cm. in width
		Aug. 10, 1928	29 cm. $\times$ 3.5 cm.	8 cm. in length 1.5 cm. in width
D	6.5 cm. $\times$ 4 cm.*	.....	.....	.....
E	18 cm. $\times$ 6 cm.	do.	10 cm. $\times$ 2 cm.	Lost 4 cm. in width, 8 cm. in length. Original body broken up during winter

* Specimen lost.

Therefore, sponge A lost approximately 18.6 c. c. during the winter, but during the next favorable season it formed 760.3 c. c. of new growth, practically four times the original volume. By the same method it is found that sponge 6 of Table I had on August 10, 1926, a volume of 614.9 c. c., and on August 11, 1927, 2,948.9 c. c., or a gain of over 2,300 c. c.

Any such computation was applicable only in situations sim-

TABLE II
SPONGES TAGGED ON OCTOBER 27, 1928

No.	Measurements when tagged	Date recovered	Measurements at recovery	Condition of sponge at recovery
1	38 cm. $\times$ 9 cm.*	.....	.....	.....
2	49 cm. $\times$ 9 cm.	June 22, 1929	43 cm. $\times$ 5 cm.	Old colony dark brown; three green patches, 1 cm. sq., on surface
3	23 cm. $\times$ 4 cm.	do.	.....	Only traces of old colony left; branch nearly broken away
4	38 cm. $\times$ 2.5 cm.	do.	.....	Only traces of old colony left
8	28 cm. $\times$ 10 cm.	do.	.....	Like No. 3
9	15 cm. $\times$ 11 cm.	do.	15 cm. $\times$ 5 cm.	Covered with silt and slime; broken up
10	15 cm. $\times$ 8 cm.	do.	.....	Like No. 3; several patches of green growing on surface; branch broken off, but still clinging by wire to original stem
11	13 cm. $\times$ 4 cm.	do.	.....	Like No. 9; several green growths on surface
12	25 cm. $\times$ 9 cm.	do.	.....	Like No. 11
13	23 cm. $\times$ 6 cm.*	.....	.....	.....
16	30 cm. $\times$ 8 cm.	do.	.....	Like No. 11
17	11 cm. $\times$ 3 cm.	do.	.....	Nothing left of old colony between wires
		do.	.....	Few irregular broken patches of old colony remaining
18	23 cm., flat type	Aug. 21, 1929	20 cm. $\times$ 2.5 cm.	Lost 3 cm. in diameter, but gained in thickness
21	8 cm., flat type	June 22, 1929	.....	Only marker recovered
22	10 cm., flat type	do.	.....	Only traces of old colony left; covered with silt and slime
23	19 cm. $\times$ 7 cm.	do.	.....	Broken up; found on bottom of stream

* Specimen lost.

ilar to those in Bessey Creek, where the numerous colonies almost invariably grew on fairly slender limbs of small trees whose tops had fallen into the water. On these slender supports the general tendency of the colony was to assume the form referred to above,

particularly after it had become large enough to encircle the limb completely. Colonies thus approximate the spindle shape, with the greatest thickness at the middle, and a thinning off toward the extremities. Obviously a different method of arriving at a measure of increase in volume would have to be used for sponge colonies of other forms.

Although the experiments described above and one field observation are not wholly conclusive, they suggest the following probabilities: (1) that sponges inherently remain intact, if possible, during unfavorable conditions and build anew upon and among the old structure to form larger colonies, the size of which depends on the base of attachment, i.e. a thin twig can carry only a certain weight, but a larger support allows development of a larger sponge; (2) that sponge bodies normally die at the close of the favorable season after producing gemmules to assure reproduction at the renewal of favorable conditions; (3) that summer growth begins immediately after the renewal of favorable conditions, as it did, for example, in a pond near Ann Arbor as early as the last week in March; and (4) that this growth in one season may exceed 2,500 c. c.

GEMMULE SPICULES IN IMMATURE FORMS

Sponges collected during the early summer months may not show gemmules, but often in the making of slide preparations for the various kinds of body spicules gemmule spicules are also encountered. The writer believes that their presence may be explained by results of the experiments in yearly growth. Since the sponge body may remain intact, if external conditions permit, the gemmules are not liberated and, even after germination, parts, at least, of the gemmules must remain in the body and so account for gemmule spicules. Accidental inclusion of old gemmules liberated upstream from other sponges is not probable for two reasons: (1) unless the stream is a fairly swift one, the gemmules sink to the bottom, being weighted down by the siliceous spicules; (2) even if such a thing should happen, one would also expect to find gemmule spicules of different species, or at least some gemmule spicules that do not fit in with the other

spicules of the sponge in question. Such spicules were never found.

PERENNIAL GROWTH

It is known that some sponges do not necessarily die at the approach of winter. Potts (1887) has found green, growing specimens of *S. aspinosa* throughout the winter; Crowell (1926) reports *Heteromeyenia ryderi* in ice-covered streams; and the writer has often collected *S. lacustris* at depths of from three to six feet in Third Sister Lake, near Ann Arbor, Michigan, during the winter season. Nearer the shore and at shallower depths the same species became abundantly filled with gemmules in the fall and died. Occasional sponges found growing during the winter have possessed gemmules, and one specimen of *H. ryderi*, collected by Crowell, had gemmules. So far, the belief has been that none of these "evergreen" sponges form gemmules, but that they modify themselves otherwise to withstand the low temperatures. According to Weltner (1893), Lieberkühn has reported the absence of flagellated chambers, Metschnikoff found no canals, and Wierzejski found neither canals nor flagellated chambers in *E. fluviatilis* in the winter. Weltner repeated the work and found flagellated chambers and canals, but restricted in size in the winter, which suggested a dormant condition. Wierzejski believed it to be an embryonic condition similar to that of the gemmule content. Though the writer has nothing to add to our knowledge of these anatomical conditions during the winter, there are two facts which present themselves: (1) sponges which normally form gemmules may nevertheless, on occasion, become perennial; (2) even sponges having regularly formed gemmules apparently may continue to live through the winter.

REPRODUCTION DURING THE SUMMER

Thousands of small colonies of sponges, varying from one-half to five mm. in diameter, living on the recent growths of submerged vegetation, were found in Bessey Creek by Professor Paul S. Welch on August 17, 1926. The writer has never witnessed a case like that, but he has collected in different waters where similar small sponges occurred in large numbers together with

sponge colonies which were of a large size and possessed gemmules. It could not be definitely shown whether these small sponges were the result of that season's crop of gemmules or of sexual reproduction. Though sexual reproduction is generally supposed to take place at the beginning of the favorable season, it nevertheless appears from general considerations that these small sponges may be due to fertilized ova. Their abundance and their uniformly small size suggest a haphazard settling of the free-swimming sponge larvae.

II. ASSOCIATED MACROÖRGANISMS

The microorganisms and the macroorganisms associated with fresh-water sponges have received attention from many writers, among whom are Annandale (1907, 1911, 1916), Lieberkühn (1856), Needham (1901), Stebbing (1907), Stephenson (1910), Viets (1927), and Weltner (1894). In conjunction with various studies on fresh-water sponges the writer collected whatever macroorganisms were on or in the sponge.

The organisms were as follows: larvae of Chironomidae, Dytiscidae, Ephemeridae, Odonata, Simuliidae, Sisyridae, and Trichoptera; Amphipoda; Bryozoa; Gordiidae; Hirudinea; Hydra-carina; Isopoda; Mollusca; Nematoda; and Oligochaeta. With the exception of *Gordius*, all have been previously reported. This specimen of *Gordius* was found entwined in and about the base of a branched colony of *S. lacustris* in a narrow, shallow stream. Its presence, as may also be true of all except the Sisyridae, was probably accidental. Certain forms, such as Trichoptera and chironomid larvae, occur in very frequent association with the sponge, and it seems that these forms may actually seek the sponges. In Third Sister Lake one sponge, *S. lacustris*, yielded various stages of the water mite from the egg to an adult, which was identified by Professor Ruth Marshall as *Unionicola crassipes* (Müll.). It is believed that this common hydrachnid may be parasitic on sponges.

No study has been made of the relationships of the various species to sponges, but it appears that the list of forms found represents a somewhat graded series from the purely accidental

to the completely necessary. There are those, such as the sisyrids, which have an inseparable relation with sponges; others, such as the caddis fly and chironomid larvae, oligochaetes, nematodes, etc., may find at least a retreat in the sponge body, and it is not wholly inconceivable that they may find in it accumulations of food materials. If the sponge acts as a screen, sifting material out of the water with consequent accumulation within the surface irregularities, why should not animals discover and take advantage of it?

It is also likely that insects may aid in the dissemination of sponges, at least from one part of a continuous body of water to another. This has already been mentioned by Kreeker (1920), who found that the parchment-like cases of caddis worms in Lake Erie were encrusted with small sponges. The writer has also noticed this condition in sponges from a lake and a pond near Ann Arbor, where caddis worms which have cases of the log-cabin type were encrusted with sponges, as were also the parchment cases.

III. CULTURE EXPERIMENTS

No one has ever reared fresh-water sponges under laboratory conditions. Sponges allowed to remain a few days in unreplenished water quickly become foul, release a most offensive odor, and disintegrate. Renewal of the water only delays disintegration.

Potts (1887), Brocher (1913), and Van Trigt (1919) have devised methods by which sponges have been kept for several months in aquaria. The containers varied from small vessels of one-liter capacity to larger vessels of one hundred liters, and the water was renewed either continuously by tap or at intervals of a day or two. Van Trigt was able to keep *Spongilla* in this fashion from one to one and one-half months, and *Ephydatia* usually lasted five months.

For true laboratory culture, sponges must not merely exist for several months but actually thrive for periods sufficiently long to duplicate their existence in nature and to reproduce. With experimental facilities and ample materials at hand, the writer undertook the solution of this puzzling problem of sponge-culture.

As will be shown, all the attempts were negative. Nevertheless, the methods and the results are presented, since they may contribute to the construction of new methods for a future attack. It is highly desirable, from many standpoints, to discover the explanation for true laboratory culture of fresh-water sponges.

OBSERVATION AND RESULTS

During the summers of 1926 and 1927 several experiments were made at the Biological Station of the University of Michigan, Douglas Lake, Michigan. The facilities included a pump and giant storage tanks, which furnished a continuous supply of unmodified lake water for the aquaria. Presumably this water was suitable in all respects, since sponges grow in certain parts of the lake. In the laboratories of the Department of Zoölogy, University of Michigan, culture experiments were continued during the period from 1926 to 1929.

Experiment 1. — Three glass aquaria, $10\frac{1}{2} \times 12 \times 18$ inches, filled with lake water, were arranged in line and connected with one another by glass siphons, so that the water of one aquarium flowed over into the next. All aquarium bottoms were covered with sand in which were anchored a few common water plants. The set-up stood under a shelter on the east side at an open window considerably shaded by trees. After lake water had been running through the aquaria five days, sponges were added and notes taken daily on their general appearance. Limnological analyses show that the water of Bessey Creek near its mouth is very similar to that of Douglas Lake, into which it flows. It may be noted also that a few sponges have been found in that part of the lake. The sponges used varied from spindle-shaped colonies, 3×1 inches, to flat, subcircular colonies, one-eighth inch in diameter. Some were green, others a pale brown. The object of attachment may have been gravel, wood, branches, or vegetation.

At the end of eight to fourteen days the colonies presented a thin, emaciated, spinose condition. The green sponges became covered with heavy growths of filamentous algae, which could be washed off, but in any case the sponges became paler and finally

white. The non-green sponges developed no filamentous growths, but deteriorated similarly and became white; a few became moldy. At no time was any offensive odor noticeable; the odor was always that of the fresh sponge, but not so strong.

Experiment 2. — To make certain that collection and transportation of sponges from the field to the laboratory was not at fault, three sponges were taken out of Bessey Creek, put into a galvanized iron pail, carried around with deliberate carelessness for thirty minutes, and then left standing in direct sunlight for forty more minutes. After this treatment they were returned to their original resting place in the creek and tagged. Fifteen days later examination showed them to be as healthy as they had been before the treatment. Evidently proper transportation has little, if any, effect.

Experiment 3. — A second set-up was made in the same spot as that of Experiment 1. Two aquaria with sand bottoms each received a continuous supply of unmodified lake water by separate inlets at the rate of four gallons per hour, with excess water leaving at the surface. On July 7, 1927, two small green sponges were placed in each aquarium to test the effect of an abundant water supply. On July 16, 1927, they were still green, but had lost their porous character. The odor was that of a fresh specimen. On July 26, 1927, the sponges were very much emaciated; one was covered by a mold.

Experiment 4. — The inlet tubes of two aquaria were provided with a Y-tube, one arm of which, being left open, allowed air to be carried into them with the unmodified lake water. Sponges fared no better in these aquaria; one spindle-shaped colony coating a slender branch became so emaciated by the end of sixteen days that it slipped along the branch to the bottom. Other sponges inserted at different times retained a healthy aspect from seven to sixteen days.

Experiment 5. — Since these aquaria stood in a shaded place, another one was set up outside the shelter, where it received subdued sunlight from noon to sunset. Otherwise the conditions were identical with those of the previous experiment. On July 19, 1927, two spindle-shaped green colonies, $3\frac{1}{2} \times 9$ inches and

$\frac{3}{4} \times 3$ inches, were placed in it. These sponges seemed to fare better; not until three weeks later was there an appreciable difference in color. With this change the surface developed a sort of velvety smoothness, with loss of porous nature. A few days later, however, the sponges were thin and scraggy, and the sides of the aquarium became lined with slimy green patches.

Experiment 6. — This set-up consisted of six aquaria with gravel bottoms, in which circulation of water was accomplished by allowing compressed air to accumulate in the large end of inverted glass funnels in one aquarium, and thus force the water over into other aquaria. It returned to the first aquarium by way of siphons. Lake water was used exclusively. This automatically provided the proper food materials as well as the proper kind of water. Branched colonies of *S. lacustris* were introduced after the water in the aquaria had been running for four days, but the sponges lapsed into pale, deteriorating bodies in from three to ten days. Experiments were run over a period of two months; in all, the results were similar.

Experiment 7. — Since Potts (1887) found that gemmules germinated and grew for some time in a glass bowl containing only tap water, it was decided to attempt an experiment with tap water only. With the set-up of the previous experiment, and tap water instead of lake water, another series of colonies of *S. lacustris*, together with *E. mülleri*, were observed over a period of six months. Again the healthy sponge degenerated into a fragile body of spicules.

Experiment 8. — Two aquaria were set up with four-inch, six-paddle wheels. One wheel was placed so that about two thirds of it was out of the water. The wheel was revolved by a jet of compressed air against the upper blades, which in turn imparted a movement to the water. By regulating the force of the jet of air and the consequent speed of the wheel the water could be made to rotate more slowly, or faster. Another wheel was placed near the bottom of the aquarium at the middle of one end; air bubbles rising from a tube properly placed made the wheel revolve and gave to the water a motion that was both upward and downward, as well as rotation. Lake water was added every

three or four days. The purpose of the paddle wheels was to cause a movement of the water, which served to duplicate, in a way, the movement of water in a stream and to bring any food materials in the water within closer reach of the sponges. Observations over eight weeks on sponges added periodically yielded negative results; the sponges lasted only from four to eight days.

Experiment 9. — One large aquarium, $14 \times 15 \times 25$ inches, was filled with tap water and continually aerated. Additions of lake water were made at intervals of from three to four days. Five goldfish were also transferred to this aquarium and fed, twice a week, with a carbohydrate-protein preparation. Specimens of *S. lacustris*, which had been collected in the fall and which had already formed a few gemmules, continued to form them in the aquarium. Some filaments became filled with gemmules; others had few or none. A few specimens which had no indications of gemmules when brought to the laboratory developed some in five to ten days. In the latter case, however, the gemmules were very small, possessed no spicules, and were wont to germinate only after about five months; they produced small green patches that persisted for only three to ten days. Normal gemmules, either those brought in as such from the lake or those formed in the aquarium, remained inactive from two to four months, after which they germinated. When placed in the aquarium most of the gemmules began to germinate about two months after being collected, and continued a slow growth from six to seven weeks. Some of the growths, one-sixteenth to one-eighth inch in diameter, occasionally coalesced to form a green mass, $1\frac{1}{2} \times \frac{1}{8}$ inches, after which the mass gradually disappeared. Others produced a few naked gemmules, which in turn germinated in about ten days and then disappeared.

Experiment 10. — Portions of *S. lacustris* bearing gemmules were brought to the laboratory in October and kept in finger bowls in constantly aerated lake water. In the following February twelve pieces of this sponge, containing numerous gemmules, were transferred to tall, narrow glass vessels filled with tap water and set outside the laboratory window, where they remained until April. During this time the water froze and thawed ten times. Five

days after the specimens had been brought inside, gemmules of six pieces showed signs of germinating and were removed to constantly aerated tap water. This tap water received additions of lake water and the carbohydrate-protein preparation for the goldfish. Thirty-one days later all signs of sponge life had disappeared, and the sides of the aquarium were covered with slimy brown patches.

Experiment 11. — Gemmules which had been gathered in the fall and which had been kept in aquaria at temperatures above freezing were placed in watch glasses to find out whether they would germinate without subjecting them to freezing temperatures. They were placed in watch glasses, one to five in a glass, containing tap water, lake water, or distilled water. To prevent evaporation one set of eight glasses was covered with extra glasses. Another set of eight was left open. Thirteen days later all gemmules of the first set had begun to germinate, and gradually increased in size, forming a body, one-fourth to one-half inch in diameter. The gemmules germinated and grew equally well in tap water, lake, or distilled water. Food was supplied from three to five days after germination by adding fresh lake water to some, organic debris and soil to others, and protozoan cultures to still others. In all cases, after the eighth day, the sponges grew pale and deteriorated, occasionally becoming moldy. Dishes not covered had to have water added daily, owing to the loss by evaporation. These gemmules did not germinate until twenty days later. Two days after this time they were placed in aquaria, but they deteriorated in from five to eight days.

DISCUSSION

All the results of the sponge-culture experiments are negative. Growing sponges or their internal buds apparently continue their biological activities for a few weeks, but can survive the artificial environment for only a few days. Failure does not appear to be due to lack of food, since it was furnished by the water from the original habitat, or by organic debris and soil from the same source. Oxygen requirements were met by continual aëration. The pH of 8.0 to 8.2 is within their range of tolerance as they have been

found in natural habitats in Michigan by the writer. The water was circulated to aid them in obtaining their necessities in it.

In the shallow, natural bodies of water gemmules may be frozen for some time. Potts (1887) grew *S. lacustris* from gemmules frozen during the winter. Williams (1897) found in laboratory experiments that freezing did not, in general, affect the germinative power of gemmules. During experiments lasting two months the writer was able to germinate gemmules that had frozen and thawed ten times in periods that averaged three days. This indicates that in nature freezing, at least encasement in ice, is not necessarily fatal to gemmules. There are zoologists who believe that gemmules *must* undergo freezing before they germinate. This is not the true case, since gemmules protected from freezing also germinated.

In all parts of the world gemmules undergo a quiescent period before germinating. This period corresponds to the dry period of the tropics or the winter period of the temperate and arctic countries. It has been inferred in the literature that a quiescent period is necessary before gemmules are able to germinate. The experiments of the writer also seem to confirm this notion, for conditions, at least so far as temperature was concerned, were favorable, yet no germination occurred until a minimum of two months later. Abnormal gemmules formed in the aquaria rested only fifteen days before germinating.

Since cultural experiments were done by the writer in advance of the environmental work, there was no chance to make use of the information accumulated on optimum sponge habitats (Ord, 1932). However, from the observations made on more than one hundred natural habitats in Michigan, the author, at the present time, would not attempt further experiments with ordinary small glass aquaria, but would substitute larger shallow basins with such accessories as would tend to duplicate natural conditions more fully. Two specimens of sponges were found in shallow streams or standing water that were but one and one-half to three feet wide as well as in the larger streams. Sponges were found in small shallow ponds also, but most of them were quite small and produced gemmules apparently earlier than did the

sponges in larger bodies of water. Early production of gemmules, together with small body size, suggests a habitat that is unfavorable. The better arrangement, then, would be to try to duplicate factors of flowing waters. Probably a shallow, long basin or trough with an abundant, continuous supply of water containing food organisms or materials would solve the problem.

SUMMARY

1. Fresh-water sponges tend to remain intact during the winter, and build anew the following spring upon and within the old structure.

2. A list of associated macroorganisms is presented, with suggestions concerning the relationships, purely accidental to obligate, between them and sponges.

3. Gemmules appear to withstand freezing, and alternate freezing and thawing. Further evidence that gemmules require a quiescent period before germinating is presented.

4. The continuous culture of fresh-water sponges is still an unsolved problem.

ACKNOWLEDGMENTS

The author is indebted to Professor Paul S. Welch under whom this work was conducted. Acknowledgments are due also to Professor George R. La Rue for the use of the facilities at the Biological Station of the University of Michigan.

URSINUS COLLEGE

COLLEGEVILLE, PENNSYLVANIA

LITERATURE CITED

- ANNANDALE, N. 1907. The Hosts of *Tachaea spongillicola*, Stebbing. *Rec. Ind. Mus.*, 1 : 279.
- 1911. Freshwater Sponges, Hydroids and Polyzoa. *Fauna of British India*. 251 pages. London.
- AND KAWAMURA, T. 1916. The Sponges of Lake Biwa. *Journ. College Sci., Imp. Univ. Tokyo*, 39 : 1-27.
- BROCHER, F. 1913. *L'Aquarium de Chambre*. 451 pages. Paris.
- CROWELL, M. F. 1926. Notes on Gemmules and Spicules in *Heteromeyenia ryderi* Potts. *Occas. Pap. Boston Soc. Nat. Hist.*, 5 : 203-206.
- KRECKER, F. H. 1920. Caddis-worms as Agents in Distribution of Fresh-water Sponges. *Ohio Journ. Sci.*, 20 : 355.
- LIEBERKÜHN, N. 1856. On the Development of the Freshwater Sponges. *Ann. Mag. Nat. Hist.*, 17 : 404-413.
- NEEDHAM, J. G., AND BETTEN, C. 1901. Aquatic Insects in the Adirondacks. *Bull. New York State Mus.*, No. 47.
- OLD, M. C. 1932. Environmental Selection of the Fresh-Water Sponges (Spongillidae) of Michigan. *Trans. Am. Microsc. Soc.*, 51 : 129-136.
- POTTS, E. 1887. Fresh Water Sponges. A Monograph. *Proc. Acad. Nat. Sci. Phila.*, pp. 157-279.
- STEBBING, T. R. R. 1907. A Freshwater Isopod from Calcutta. *Journ. Linn. Soc.*, 30 : 39-42.
- STEPHENSON, J. 1910. On Some Aquatic Oligochaete Worms Commensal in *Spongilla carteri*. *Rec. Ind. Mus.*, 5 : 233-240.
- VAN TRIGT, H. 1919. A Contribution to the Physiology of the Fresh-water Sponges (Spongillidae). 220 pages. Leiden.
- VIETS, K. 1927. *Atractides spongicolus* n. sp., eine Hydracarine aus einem Süßwasserschwamm von Celebes. *Zool. Anz.*, 71 : 109-112.
- WELTNER, W. 1893. Spongillidenstudien II. *Arch. f. Naturgesch.*, 59 : 245-284.
- 1894. Anleitung zum Sammeln von Süßwasserschwämmen nebst Bemerkungen über die in ihnen lebenden Insektenlarven. 8 pages. Berlin.

OBSERVATIONS ON THE SISYRIDAE (NEUROPTERA) *

MARCUS C. OLD

IN THIS country the only contribution to the general biology of the spongilla flies or Sisyridae has been made by Needham and Betten.¹ Their life-histories are not known, since attempts to rear them have been unsuccessful, owing to the fact that they are dependent upon living fresh-water sponges. A few observations on larvae, pupae, and imagoes were made by Needham, who found them on sponges growing in water-supply troughs in a fish hatchery.

During the summers of 1926, 1927, and 1928 at the Biological Station of the University of Michigan, Douglas Lake, Michigan, the writer collected many larvae of Sisyridae, which he transferred to the laboratory in order to continue observations on their activities. They were placed in finger bowls containing water, a thin layer of sand, and a pebble large enough to extend above the water. Pieces of fresh sponge replaced old pieces every day. The larvae sometimes fed on the sponge, sometimes not. Often they showed no evidence of even being aware of its presence. Thirty-eight larvae, distributed in ten finger bowls, varying in size from 0.5 to 4.0 mm., were treated thus. About 60 per cent of them died within two to ten days. Of the remaining 40 per cent which pupated, 80 per cent emerged in from eleven to fifteen days. At pupation the larvae had a length of 3.5 to 4.0 mm.

* Contribution from the Biological Station and the Zoölogical Laboratory of the University of Michigan.

¹ Needham, J. G., and Betten, C., "Aquatic Insects in the Adirondacks," *Bull. New York State Mus.*, No. 47. 1901.

Immediately before pupating the larvae walked excitedly over the exposed surface of the pebble, now hurriedly and then feebly, for forty-five to seventy-five minutes. Having finally selected a site, usually a small notch or angle, they would wave their antennae and at the same time indulge in telescopic movements of the abdominal segments. Some would spin hemispherical nets over themselves before forming their cocoons; others would make the cocoons without first enclosing themselves in silken cages. According to Needham, only *Climacia* builds the hemispherical net.

The purpose of this loosely woven net is not known. It might serve as a protection from certain parasitic insects. It does not, however, protect the pupa from becoming wet during submergence, as was shown by experiment.

A larva swims about by a peculiar body movement. It holds itself in a vertical position, head up, arches the body, and then,



FIG. 77. Swimming movements of larvae of Sisyridae

by snapping back into the vertical position, produces a forward movement. See Figure 77.

During the summer of 1927 many pupae and larvae were collected at the mouth of Maple River, Burt Lake, south of Douglas Lake. Field trips to this locality yielded more than five hundred pupae, some of which contained parasitic Hymenoptera. Both *Sisyra* and *Climacia* cocoons occurred in abundance on *Scirpus* culms at rough spots or in the spikelets. Many were found alongside gyrinid cocoons on these same stems. Groups of from four to eight cocoons, side by side, were common. Cocoons were also found in exposed snags. Many larvae were just coming out of the water and walking up the *Scirpus* stems. These, when brought to the laboratory and placed in vials, immediately pupated, and emerged in from eight to fourteen days.

In Nigger Creek, near Mullet Lake, which is southeast of Douglas Lake, many sisyrid cocoons were found on the under side of stones above water. Stones partly in the water, but with their under sides concave and forming a small chamber above water, also yielded numerous cocoons.

Pupae brought into the laboratory emerged and afforded material for experiments on life-history. Twenty-five cocoons were placed in a natural position over an aquarium containing sponges and water plants, the latter projecting above the surface of the water. A cage of cloth netting was adjusted over the aquarium. As the imagoes emerged, they flew to the top of the cage, sought a secluded corner, and remained there, rarely flying about. From three to five days later the flies could be picked from the surface of the water, where they had fallen. They appeared very weak in flight, and the slightest wetting rendered them unable to extricate themselves. Examination of the water and plants revealed no evidence of eggs. Repeated observations yielded no results. Flashing a light on imagoes at night caused them to fly about toward the light and exhibit positive phototropism.

During the collection of sponges throughout the State of Michigan in 1929 the writer found many sisyrid larvae. They were recovered from sponges in habitats whose pH varies from 6.2 to 8.5. They were not found on the following species of fresh-water sponges: *Ephydatia fluviatilis*, *Heteromeyenia repens*, and *H. argyrosperma*. This suggests that Sisyridae may be found to show a specificity for certain species of sponges. Absence of larvae in *H. repens* and *H. argyrosperma* may be due to the fact that so few specimens of these species were collected, but, on the other hand, it should be pointed out that quantities of *E. fluviatilis*, without any larvae, were found at various points in the Grand River, a polluted stream, near Lansing. It remains uncertain, however, whether the absence of larvae in the Grand River is due to a difference in the sponge or to contamination. Five other collections of *fluviatilis* from uncontaminated waters showed this same absence of larvae.

It is not possible at the present time to identify with certainty

the different species of sisyrnid larvae, hence nothing can be stated concerning the relation of different species of larvae to different species of sponges. Intensive work on this unique family of insects is planned for the future.

URSINUS COLLEGE
COLLEGEVILLE, PENNSYLVANIA

